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ERRATA.

Page 52, line 4 from bottom, *for* oxygonum *read* oxygonus.

— 115, — 17 from top, *for* Secretary *read* President.

— 190, and Plate XXI. fig. 1, *Tellina Sobralensis* is erroneously stated to be from subcretaceous beds between Sobral and Torres Vedras; it belongs to the "Almada Beds" of the Tertiary Series, having been found at Portella, about four miles north of Lisbon on the road to Saccavem. The original specimen was received mixed with others from the former locality, and the error was only discovered after the publication of the paper. This species must therefore be struck out of the lists at pp. 154, 172, and 200.

— 331, line 7 from top, dele *Eschara*: PL. XVIII. f. 8.

— 370, — 10 from top, for *Cerbero* read *Cerboli*.

— 454, — 2 from top, after *Ammonites* read *biplex*, Sow.

Directions to the Binder.

The Binder is directed to place at p. 190 the loose slip issued with No. 24, and containing the erratum respecting *Tellina Sobralensis*.

THE

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PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

April 18, 1849.

The following communications were read:—

1. *Palichthyologic Notes.* No. 3.—*On the* Ganoidei Heterocerci. By Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S.

This family has been considerably reduced, since the publication of the 'Poissons Fossiles,' by the new arrangement of the fishes of the old red sandstone and their allies contained in the 'Monographie des Poissons du Vieux Grès Rouge' of M. Agassiz. A further reduction became recently necessary in consequence of the discovery of the true affinities of the genus *Platysomus**. As at present constituted, the genus *Amblypterus* stands at the head of the family.

Genus Amblypterus, Ag.

Of this genus Agassiz has described nine species, but one of these he subsequently cancels, namely *Amblypterus Olfersi* from Brazil, which forms the type of his new genus *Rhacolepis*†. Since the publication of Agassiz' work, Professor Goldfuss has described in great detail the characters of the scales of *Amblypterus macropterus*‡, which rarely occur in a good state of preservation. He enumerates

* Palichthyologic Notes, No. 2. p. 329. † Poiss. Foss. vol. ii. part 2. p. 283.
‡ Beiträge zur vorweltlichen Fauna des Steinkohlengebirges, p. 20.

six variations in the sculpture of the enamel. In five of these the scale is divided by a diagonal line extending from the upper anterior to the lower posterior angle, of various degrees of curvature. The scale is traversed by from twenty to four-and-twenty striæ; those, on one half of the scale, sometimes the upper, sometimes the lower, run parallel to the diagonal line; those on the other impinge on it at various angles. The sixth variety has a raised ridge in place of the diagonal line to which the striæ converge on either side. The latter form of scale occurs behind the pectoral fins. He describes the head bones as ornamented with granules, closely arranged in radiating lines. The teeth he affirms to be strong and conical (*kegelförmig*), not *en brosse* as stated by Agassiz*.

(*New Species.*)

AMBLYPTERUS PORTLOCKI, Egerton.

Colonel Portlock, in his 'Report on the Geology of the County of Londonderry, and of parts of Tyrone and Fermanagh†,' mentions some scales as probably belonging to this genus, found in the coal shale of Ballycastle, in the clay and marl of Moyola in the parish of Maghera, and in Fermanagh. I have two specimens, one from Moyheeland near Draperstown, the other from Maghera, apparently belonging to the same species, which being new, I propose to designate by the name of the discoverer. The specimens are very imperfect, but the character of the scales is sufficient to distinguish the species from those hitherto known. The specimen from Moyheeland shows the insertion of the pectoral fin, and a portion of the humerus. The surface of the latter is covered with broad flattened plicæ running nearly parallel with the curvature of the bone. The rays of the fin are strong, and appear to have been less numerous than is generally the case in this genus. The scales are large for the size of the fish. They are very thick, and are ornamented on the entire surface with strong prominent ridges, fewer in number and coarser than in any other Amblypterus, so much so that a single scale is quite enough to indicate the species.

Genus EURYNOTUS, Ag.

This genus was arranged by Agassiz between the genera *Palæoniscus* and *Platysomus*, and was considered to have affinities to the latter genus and *Amblypterus*‡. In consequence of the discovery of the dentition of *Platysomus* and its removal to the family of the *Pycnodontidæ*, it was necessary to inquire into the propriety of retaining *Eurynotus* in the position originally assigned to it. This examination became more necessary in consequence of a letter received not long ago from Mr. Hugh Miller, communicating the discovery of a group of rounded palatal teeth in a specimen of *Eurynotus crenatus* found in the neighbourhood of Crail in Fifeshire. I have since received a very accurate cast of this specimen showing the teeth *in situ*. These at first sight would seem to indicate a Pycnodont, but a comparison

* Poiss. Foss. vol. ii. p. 30. † Page 462. ‡ Poiss. Foss. vol. ii. p. 153.

of the dentition of this family with other fishes having blunt rounded teeth, especially with *Lepidotus* and *Tetragonolepis*, shows that there is so great a difference in the arrangement of the teeth in the two families, that even without the test of microscopic examination, the true affinities of the fish can be determined. In the form and arrangement of the scales and in other important respects, *Eurynotus* differs entirely from the *Pycnodontidæ* and agrees with the *Lepidoidei*. It certainly resembles *Platysomus* in the depth of the body and extent of the dorsal fin, but the former character is also common to *Amblypterus*, and the structure of the dorsal fin is more in conformity with that of this organ in *Palæoniscus*. The discovery of the dentition of *Eurynotus* is not without interest, inasmuch as it tends to invalidate the dental characters assigned by Agassiz to the Lepidoid family, and to show that although these fishes may have had "Dents en brosse sur plusieurs rangées, ou une seule rangée de petites dents obtuses*," yet that some of these had (perhaps in addition to those described by Agassiz) teeth of a larger and more massive character. Thus in the genus *Amblypterus* the teeth are described in the 'Poissons Fossiles' as "dents en brosse extrêmement fines†," while Goldfuss says "dass die Zähne nicht bürstenförmig sondern stark und kegelförmig sind‡." Some of the *Palæonisci* also have teeth which cannot be considered as "dents en brosse," especially the American species, now arranged under the genus *Ischypterus*. It is therefore not unlikely, that as in some of the homocerque Lepidoids we find teeth of various forms and sizes associated in the same individual, so a similar condition may have obtained in their heterocerque predecessors. Of the three species of *Eurynotus* described by Agassiz, one, viz. *Eurynotus tenuiceps* from Massachusetts, is considered by Mr. W. C. Redfield to be an imperfect specimen of *Palæoniscus* (*Ischypterus*) *latus*§.

Genus Plectrolepis, Ag.

Agassiz in his 'Tableau Général' mentions a genus under this designation from the coal-measures of Carluke. I have not seen the specimens on which it was founded, but Lord Enniskillen has a fish from the same locality which represents so truly the character expressed in the title, that I feel little hesitation in referring it to this genus. In size and form it resembles a moderate-sized *Palæoniscus*, but it differs widely in other respects from that genus. The scales are very solid, and covered by a coat of dense, highly lustrous ganoine. The posterior margin is armed with four or five sharp and strong spines, whence the generic name. The bones of the head are covered with coarse wrinkles; the teeth are blunt, resembling those described above as having been found by Mr. Miller in *Eurynotus crenatus*. The dorsal fin is situated very far forward, nearer to the head than in any genus of this family. The upper lobe of the tail is covered by a

* Poiss. Foss. vol. ii. p. 1. † Vol. ii. p. 30, line 23.

‡ Beiträge, p. 20.

§ Short notices of American Fossil Fishes; read before the Yale Nat. Hist. Soc. April 28, 1841.

series of strong ridge-shaped scales. The specific name given by Agassiz is *rugosus*, probably in allusion to the rugged character of the cranial bones.

Genus Palæoniscus, Ag.

This genus embraces a greater number of species than any other of the Heterocerque Lepidoids. Not only in species but in individuals the *Palæonisci* appear to have been the most numerous of the vertebrate denizens of the waters in which they flourished, associating together in large shoals, and performing no doubt important functions in the then economy of nature, probably by reducing and assimilating the superabundant vegetable substances brought within their reach, and again in their turn forming the prey of the *Megalichthys*, *Holoptychius*, *Acrolepis*, *Pygopterus*, and other voracious sauroid fishes with which they co-existed. Agassiz has described twenty-one species in the 'Poissons Fossiles,' including *Palæoniscus fultus*, which forms the type of the genus *Ischypterus* and will be alluded to hereafter. In addition to these he mentions in his 'Tableau Général' five others as undescribed, besides the American species *P. Agassizii* and *P. macropterus*.

Palæoniscus catopterus, Ag.

Although the discovery of this species in the new red sandstone of the county Tyrone was communicated to the Geological Society by Sir Roderick Murchison so long ago as 1835*, yet no description of the fish has yet been published. It was assigned to the genus *Palæoniscus* by Agassiz, who very happily noted its most distinctive character in the specific appellation *catopterus*. In size it is the smallest, in form the most slender species of the genus. The head is small and more pointed than in other *Palæonisci*; the eye is placed forward; the mouth appears small; the operculum is nearly semicircular. The dorso-ventral series of scales are very regular and distinct. The scales themselves are large, and of very uniform size over the whole body. The specimens hitherto found are not in a condition to show the superficial characters of the scales, the impressions of the under sides alone being preserved. The dorsal fin is placed much nearer the tail than in any other species; in this respect, but in no other, *Palæoniscus catopterus* resembles the genus *Catopterus* of Mr. Redfield. The tail is decidedly heterocerque. It is altogether so distinct from all the other *Palæonisci*, that it is recognizable at first sight.

Palæoniscus speciosus, Münst.

This is from the Kupferschiefer of Richelsdorf, and was named by Count Münster. Lord Enniskillen, who had an opportunity of seeing the specimen in the collection of M. Althaus, considers it a good species. It is as long as *Palæoniscus magnus*, but not so deep.

Palæoniscus ornatus, Münst.

This species is followed by a note of interrogation in the 'Tableau Général,' and Lord Enniskillen, who also saw this specimen, says he

* Proc. Geol. Soc. vol. ii. p. 206. Portlock, Geol. Mem. p. 468.

could not detect any specific character as differing from *P. speciosus*. It is possible some confusion may have arisen from the similar signification of the specific titles.

Palæoniscus Egertoni, Ag. Pl. I. fig. 2.

This species, although named by Agassiz during his second visit to England, has not yet been described. It was found by my brother the Rev. W. H. Egerton in the coal shale at Silverdale in North Staffordshire, and has since been discovered in Lancashire and Yorkshire, as also, I believe, in some of the Scotch and Irish coal-fields. It is a small and delicate species, somewhat less than *Palæoniscus Robisoni*. It is characterized by the scales, which are deeply furrowed and serrated at the posterior margins*. The dorsal fin is large and situated far back, its anterior insertion being very slightly in advance of the anal fin. The fin rays are strong, and dichotomise near their extremities; the transverse articulations are distant. The anal fin corresponds in size and character with the dorsal fin. The pectoral fins are small and delicate. The ventral and caudal fins are deficient. The head is smaller in proportion to the body than in any other species.

Palæoniscus Monensis, Egerton. Pl. I. fig. 3.

Lord Enniskillen found the specimens from which this species is named in the shale brought out of a coal-pit in the Isle of Anglesea, near the Holyhead road, a few miles from the Menai Bridge. They are single scales which belonged to a larger fish than *P. Egertoni*, and differ in external character from those of that species. The surface is traversed by regular parallel grooves, the ridges between these terminating in cusps at the posterior margin. In addition to these a series of fine lines is distinctly seen, bordering two sides of the scale, apparently indicating the annual increment.

Since the completion of the 'Poissons Fossiles' the following species have been made known:—

Palæoniscus Tchefkini, Fisch.

This fish, from the Permian system of the Steppe of Kargala, is figured by Fischer de Waldheim in the Bull. Nat. de Moscou. Sir Roderick Murchison† mentions three other species as probably belonging to this genus, found in the same Steppe near Orenburg.

Palæoniscus Gelberti, Goldf. Pl. I. fig. 4.

Professor Goldfuss has given this name to a *Palæoniscus* discovered by Herr Gelbert in the coal formation at Heimkirchen‡. He describes it as being longer and narrower than *Palæoniscus Duvernoy*, and as differing from all other species of the genus in the ornament of the scales. It is a handsome and well-marked-species.

* At p. 93, vol. ii. Poiss. Foss., Agassiz cancels the observation made at p. 41 as to the general smoothness of the scales of the *Palæonisci* found in the coal-measures.

† 'Russia,' page 227, note.

‡ Beiträge zur vorweltlichen Fauna des Steinkohlengebirges, p. 17.

PALÆONISCUS MACROPHTHALMUS.

M. Althaus has a specimen from the Kupferschiefer of Richelsdorf thus named. I am unable to ascertain whether it is considered identical with the species so named by Agassiz, from the magnesian limestone of this country, or whether the name has been given in ignorance of its previous application.

PALÆONISCUS MEGACEPHALUS, Germar.

A species of *Palæoniscus* from the Kupferschiefer of Mansfeld with this name, is figured and described by Kürtze in his 'Commentatio de petrifactis quæ in schisto bituminoso Mansfeldensi reperiuntur.' I am inclined to think it is founded on imperfect specimens of *Palæoniscus Freieslebeni* crushed vertically, thus giving an incorrect idea of the size of the head.

PALÆONISCUS PYGMÆUS.

M. Hermann von Meyer has given this designation to a small *Palæoniscus* of the Kupferschiefer which will be described in an early number of the 'Palæographica.'

(*New Species.*)

PALÆONISCUS BEAUMONTI, Ag. PL. I. figs. 5, 6.

This is the largest and finest species of the genus. The most perfect example I have seen was presented to Lord Enniskillen by the Baron de Ponsort, and was found in the coal shale at Autun. It measures thirteen inches in length by four in depth. In shape and appearance, if we except the heterocerque tail, it is not unlike some species of *Lepidotus*. The head is unfortunately so much dislocated that its form and proportions are not recognizable. Some of the detached bones are elaborately ornamented with a labyrinthine pattern. The scales vary much in size and form in different regions of the body. Those on the flanks immediately below the lateral line are the largest, whence they decrease in size above and below. In the vicinity of the dorsal, ventral and anal fins they are narrow oblongs; on the tail they are lozenge-shaped, elongating gradually as they approach its termination. They differ from those of every other species in the character of the exterior surface. Those immediately succeeding the thorax have from fifteen to twenty oblique parallel striæ on the middle of the scale, terminating in sharp points at the distal margin, but the upper and lower angles of the scales have no serrations. The latter character encroaches more and more upon the central portion, in the scales on the back and tail, until the striæ and serrations altogether disappear, and the scale becomes smooth on the surface and entire at the margin. The same change of character obtains more slowly on the ventral region, so that a few serrations are observable as far back as the anal fin. The fins are of moderate size with the exception of the caudal, which is very long and strong. Its upper margin is roofed with a series of large, solid, arrow-headed scales, and the lobe

itself is covered with scales to its extremity. Lord Enniskillen has also a specimen of a young individual of this species seven inches in length. It differs from the mature fish in being less deep in proportion to its length.

PALÆONISCUS DECORUS, Egerton. PL. II.

Whether we consider the elegant form and proportions of this fish, or the graceful tracery on the head, or the varied form and arrangement of its delicate scales, it must rank as one of the most beautiful species of this beautiful genus. It is rare to find among fossil fishes a highly sculptured character of the cranial bones, without the least trace of ornament on the scales of the nape and those immediately in contact with the thoracic girdle. Such however is the case in this species. All the head bones are covered with an elegant tracery of distinct lines running in tortuous courses, sometimes bifurcating, sometimes inosculating and forming intricate patterns of extreme beauty. The scales are thin and perfectly smooth, with entire margins. Those on the back are scallop-shaped, and arranged like the plates of scale-armour. In advance of the dorsal fin are four large saddle-shaped scales decreasing in size from the front. Round the base of the fin the scales are small and of various shapes, arranged in an elegant tessellated pattern. The ventral scales are oblong, and with the exception of the large plate in advance of the anal orifice, considerably smaller than those on the flanks. The latter are oblong on the anterior part of the body, rather higher than wide, but they gradually assume a rhomboidal outline as they approach the central region. The anterior margin of the dorsal fin is ornamented with a delicate fringe of fine scales; the rays composing it gradually elongate up to the eleventh or twelfth, which is the longest. This character resembles the arrangement of the dorsal fin of *Eurynotus*. The tail is of very elegant proportions; the upper lobe attenuates very gradually and is invested with scales to its minutest extremity. This species is from the coal shale of Commenterie in Auvergne. Lord Enniskillen has a specimen of *Palæoniscus*, stated to have been found near Ilfeld in the Hartz, which has considerable resemblance to this species.

PALÆONISCUS ARCUATUS, Egerton. PL. I. fig. 1.

This species has some resemblance to the preceding, but is a shorter and deeper fish. The line of the back from the head to the dorsal fin is gracefully arched, and the dorso-ventral series of scales are more curved both above and below the lateral line in the anterior part of the body than is usual in this genus. The scales are smaller than those of *Palæoniscus decorus* and thicker. The fine striæ denoting the lines of growth are clearly defined. The bones of the head are covered with flattened plicæ. The teeth in the lower jaw are numerous and very regular. The fins resemble those of *Palæoniscus decorus*, but the dorsal fin is inserted nearer to the head than in that species. The tail is wanting. This species is from the coal shale of Goldlauter.

I have a specimen presented to me by the Baron de Ponsort from the coal-measures of Liège, which differs from the genus *Palæoniscus* in the small size and pointed form of the scales, and in the greater thickness of the body immediately in advance of the caudal fin. The form of this fish is also in other respects very distinct from *Palæoniscus*. The specimen is too imperfect to describe, but perhaps this notice may produce more satisfactory materials for the determination of the generic and specific characters.

Genus Ischypterus, Egerton.

Mr. W. C. Redfield, in alluding to the description of *Palæoniscus fultus* given by Agassiz*, says, "the stout character of the fins and their insertions (which suggested to Agassiz the specific name) is also found to pertain in a greater or less degree to all the known American species of the genus, and would perhaps warrant their separation from the *Palæonisci*†." Fully concurring in this view, I suggested to Sir Charles Lyell‡ the propriety of eliminating these fishes from the Agassizian *Palæonisci* and grouping them together under the generic name of *Ischypterus*, a term expressive of the common character noticed by Mr. Redfield. Of the five species described by Mr. Redfield, Agassiz considers *I. fultus* and *I. macropterus* to be identical§. I am not cognizant of any species of this genus found at Antrim, as stated by Sir C. Lyell‖.

Genus Catopterus, J. H. Redf.

This genus has been well characterized by Mr. J. H. Redfield¶, with the exception of an error regarding the form of the tail, which has since been corrected by Mr. W. C. Redfield in the memoir quoted above**. In addition to the original species, named *C. gracilis*, Mr. W. C. Redfield has described three species; of these, *C. macrurus* must be canceled as being the type of a new homocerque genus—*Dictyopyge*††, Egerton.

Catopterus Redfieldi, Egerton.

On looking over a large collection of fossil fishes from Durham, Connecticut, forwarded to me by Sir C. Lyell for that purpose (and to whom I communicated the results), I found evidence of another species of *Catopterus*, to which I gave the above specific name in compliment to the original discoverer of the genus.

Genus Gyrolepis, Ag.

The scattered and fragmentary condition in which the remains of this genus have always been found, has proved hitherto an insur-

* Poiss. Foss. vol. ii. p. 43.

† Short notices of American Fossil Fishes, by W. C. Redfield, read before the Yale Nat. Hist. Soc. April 28, 1841.

‡ Journal of Geol. Soc. vol. iii. p. 277.

§ *Ibid.* vol. iii. p. 277.

‖ *Ibid.* vol. iii. p. 278.

¶ Annals of New York Lyceum of Nat. Hist. vol. iv. p. 39.

** American Journal of Science, vol. xli. p. 26.

†† Journal of Geol. Soc. vol. iii. p. 275.

mountable obstacle not only to a definition of its generic characters, but to a determination of the family in which it ought to be placed. It is not even known whether the tail was homocerque or heterocerque, a point of some importance as bearing upon the value of this character as a criterion of the age of strata, since some of the species are confined to the Triassic period. Agassiz has described three* species from the Muschelkalk and Keuper of Germany, two of which occur also in the bone-beds of Old Passage and Axmouth, and at Newtown Limavady in Ireland†. He mentions another species as having been found in the coal shale near Leeds. Count Münster has described a fifth species from the Trias at St. Cassian which he names *G. bipli-catus*.

Genus Coccolepis, Ag.

This genus is liable to be overlooked by those having occasion to consult the work of Agassiz, as it is described in a supplemental chapter at the end of the Observations on the Heterocerque Lepidoids; it is however worthy of especial notice as being the only one of this family hitherto found in any stratum more recent than the Trias. *C. Bucklandi* is an unique specimen in the collection of Dr. Buckland from the Oolite of Solenhofen.

Summary of Genera and Species.

Amblypterus, Ag.			
Agassizi, *Münster*	P. F. vol. ii. p. 105	Muschelkalk	Esperstädt, Thuringia.
cupterygius, *Ag.*	P. F. vol. ii. p. 36	Coal formation	Saarbrück and Lebach.
lateralis, *Ag.*	P. F. vol. ii. p. 39	Coal formation	Saarbrück and Lebach.
latus, *Ag.*	P. F. vol. ii. p. 37	Coal formation	Saarbrück and Lebach.
macropterus, *Ag.*	P. F. vol. ii. p. 31	Coal formation	Lebach and Börschweiler.
nemopterus, *Ag.*	P. F. vol. ii. p. 107	Coal formation	Newhaven.
Portlocki, *Egert.*	Geol. Journ. vol. vi. p. 2.	Coal formation	Moyola, Moyheeland and Maghera.
punctatus, *Ag.*	P. F. vol. ii. p. 109	Coal formation	Newhaven.
striatus, *Ag.*	P. F. vol. ii. p. 111	Coal formation	Newhaven.
Eurynotus, Ag.			
crenatus, *Ag.*	P. F. vol. ii. p. 154	Coal limestone	Burdie House.
fimbriatus, *Ag.*	P. F. vol. ii. p. 157	Coal formation	Newhaven.
Palæoniscus, Ag.			
angustus, *Ag.*	P. F. vol. ii. p. 57	Coal shale	Autun.
arcuatus, *Egert.*	Geol. Journ. vol. vi. p. 7.	Coal shale	Goldlauter.
Beaumonti, *Ag.*	Geol. Journ. vol. vi. p. 6.	Coal shale	Autun.
Blainvillei, *Ag.*	P. F. vol. ii. p. 48	Coal shale	Autun.
carinatus, *Ag.*	P. F. vol. ii. p. 104	Coal-measures	Newhaven.
catopterus, *Ag.*	Geol. Journ. vol. vi. p. 4.	Permian	Rhone Hill.
comtus, *Ag.*	P. F. vol. ii. p. 97	Magnesian limestone.	East Thickley, &c.
decorus, *Egert.*	Geol. Journ. vol. vi. p. 7.	Coal shale	Auvergne.
Duvernoy, *Ag.*	P. F. vol. ii. p. 45.	Coal shale	Munster-Appel.
Egertoni, *Ag.*	Geol. Journ. vol. vi. p. 5.	Coal shale	North Stafford.
elegans, *Sedgw.*	P. F. vol. ii. p. 95	Magnesian limestone.	East Thickley, &c.
Freieslebeni, *Ag.*	P. F. vol. ii. p. 66	Kupferschiefer	Mansfeld, Richelsdorf.
Gelberti, *Goldf.*	Beiträge	Coal formation	Heimkirchen.
glaphyrus, *Ag.*	P. F. vol. ii. p. 98	Magnesian limestone.	East Thickley, &c.
lepidurus, *Ag.*	P. F. vol. ii. p. 64	Permian	Scharfeneck, Ottendorf.
longissimus, *Ag.*	P. F. vol. ii. p. 100	Magnesian limestone.	Ferry Hill, Whitley.
macropomus, *Ag.*	P. F. vol. ii. p. 81	Zechstein	Ilmenau.
macrophthalmus, *Ag.*	P. F. vol. ii. p. 99	Magnesian limestone.	East Thickley, &c.
magnus, *Ag.*	P. F. vol. ii. p. 78	Kupferschiefer	Mansfeld.
megacephalus, *Germ.*	Kürze	Kupferschiefer	Mansfeld.
minutus, *Ag.*	P. F. vol. ii. p. 47	Coal shale	Munster-Appel.
Monensis, *Egert.*	Geol. Journ. vol. vi. p. 5.	Coal shale	Anglesea.

* *Gyrolepis giganteus* is an Holoptychius, Poiss. Foss. vol. ii. part 2. p. 285.

† Portlock, Geol. Mem. p. 469.

Summary of Genera and Species (continued).

Palæoniscus, Ag.			
ornatissimus, *Ag.*	P. F. vol. ii. p. 92	Coal limestone	Burdie House.
ornatus, *Münster*		Kupferschiefer	Richelsdorf.
pygmæus, *H. von Meyer*		Kupferschiefer	Richelsdorf.
Robisoni, *Hibbert*	P. F. vol. ii. p. 88	Coal limestone	Burdie House.
speciosus, *Münster*		Kupferschiefer	Richelsdorf.
striolatus, *Ag.*	P. F. vol. ii. p. 91	Coal limestone	Burdie House.
Tchefkini, *Fisch.*	Bull. Nat. de Moscou.	Permian	Bielebei.
Voltzii, *Ag.*	P. F. vol. ii. p. 55	Coal shale	Autun.
Vratislaviensis, *Ag.*	P. F. vol. ii. p. 60	Permian	Neudorf, Ruppersdorf.
———		Permian	Steppe of Kargala.
———		Permian	Steppe of Kargala.
———		Permian	Steppe of Kargala.
Ischypterus, Egerton.			
Agassizi, *Redf.*	Am. Journ. of Sci. xli. 26		Sunderland, Mass.; Boonton, N. J.; Middletown, Durham, Con.
fultus, *Ag.*	P. F. vol. ii. p. 43		Sunderland, Mass.; Boonton, N. J.; Middletown, Durham, Con.
macropterus, *Redf.*	Am. Journ. of Sci. xli. 26		
latus, *J. H. Redf.*	Ann. N. Y. Lyceum, iv. 38.		
Eurynotus tenuiceps, *Ag.*	P. F. vol. ii. p. 159		
ovatus, *Redf.*	Am. Journ. of Sci. xli. 26		Boonton, N. J.; Middletown, Con.; Sunderland, Mass.
Catopterus, J. H. Redfield.			
anguilliformis, *W. C. Redf.*	Am. Journ. of Sci. xli. 27		Middletown, Con.; Boonton, N. J.; Southburg, Con.
gracilis, *J. H. Redf.*	Ann. N. Y. Lyceum, iv. 39.		Middletown, Durham.
parvulus, *W. C. Redf.*	Am. Journ. of Sci. xli. 28		Middletown, Con.; Boonton, N. J.
Redfieldi, *Egert.*	Geol. Journ. vol. iii. p. 278.		Durham, Con.
Gyrolepis, Ag.			
Alberti, *Ag.*	P. F. vol. ii. p. 173	Trias	Germany, Bristol, Axmouth, and Newtown Limavady.
biplicatus, *Münster*	Beiträge, vol. iv. p. 140	Trias	St. Cassian.
maximus, *Ag.*	P. F. vol. ii. p. 175	Trias	Germany.
Rankinei, *Ag.*	P. F. vol. ii. p. 303	Coal shale	Leeds.
tenuistriatus, *Ag.*	P. F. vol. ii. p. 174	Trias	Germany, Bristol, Axmouth, and Newtown Limavady.
Plectrolepis, Ag.			
rugosus, *Ag.*	P. F. vol. ii. pt. 2. p. 281.	Coal shale	Carluke.
Coccolepis, Ag.			
Bucklandi, *Ag.*	P. F. vol. ii. p. 300	Oolite	Solenhofen.

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2. *On the Tertiary Deposits of the* Moray Firth *and the* Great Caledonian Valley, *with a brief notice of the Older Formations.* By the Rev. J. G. Cumming, M.A., F.G.S., Vice-Principal of King William's College, Isle of Man.

[*Abstract.*]

The district which is the subject of the present memoir has been rendered familiar to geologists by the labours of Professor Sedgwick and Sir R. I. Murchison*, whose descriptions have reference to the older rocks, and to their connection with equivalents in the English system.

Very valuable additions have since been made to these records by Mr. George Anderson of Inverness, and Mr. Hugh Miller, whose

* Transactions of the Geological Society of London, vol. ii. 2nd series, pp. 293 and 353, &c., and vol. iii. 2nd series, p. 125, &c.

Fig.5

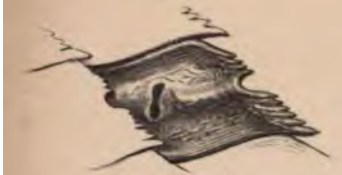

Fig 1

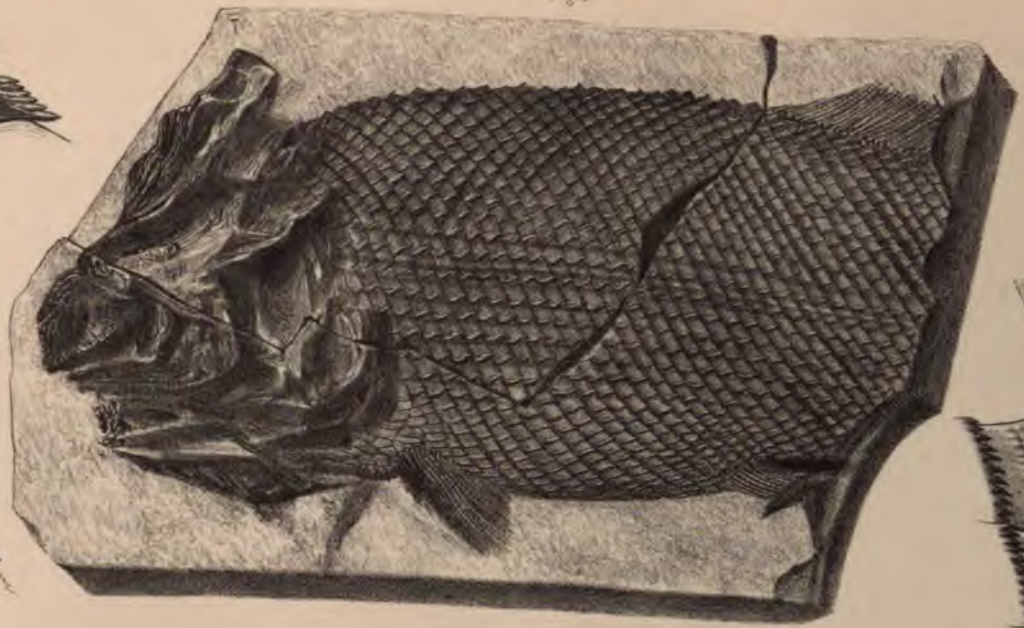

Fig 2

Fig 3

Fig 4

Fig 6

PALÆONISCUS ARCUATUS

Day & George, Lithographers, 14 Hatton Garden

accurate local knowledge, both written and oral, I was privileged to avail myself of. My attention however was chiefly directed to the distribution of the boulder-clays and the gravels of the tertiary series, and on these I venture at this time to offer a few remarks. Still, as introductory to a description of these more recent deposits, it may be useful to take a hasty view of the general physical contour of the country.

A very cursory glance at the condition of its surface must convince us that enormous denudation has occurred over the district under consideration. The now isolated masses of old red conglomerate, perched on mountain summits, must clearly at one time have formed continuous strata. We may instance particularly the fine dome-shaped mountain Mealfourvonie, on the western side of Loch Ness, rising upwards of 3000 feet above the sea. Craigora, rising to the height of 1500 feet above Temple, on the west side of the Bay of Urquhart on Loch Ness, is a round detached mass of old red conglomerate, which was obviously at one time connected with Mealfourvonie. Both these mountains rest on a base of red granite, forming nearly two-thirds of their height: and I am not aware of anything which could controvert the position, that the old red series at one time overspread the entire area of Scotland, at least north of the Clyde and Forth. The Grampians themselves were the bed of the ocean in which it was deposited.

That great disturbances had taken place amongst the schistose and granitoid rocks of North Britain prior to the deposit of the old red conglomerate is very evident, both from the want of conformity between the two series, and the varying thickness of the conglomerate within very limited areas, showing that there were great irregularities in the then sea-bottom; but I am not aware of any such *general* thinning-out of this deposit on the flanks of the great mountain masses, as to lead to the view that any considerable portion of them was eminent above the ocean-level at that time; and such evidence as we have seems to bear the other way*.

Of the extent of the disturbance which took place over this northern area, between the periods of the old red sandstone and the lias, there must always be much uncertainty, the subsequent denudations having been to such an extent. That somewhat of the present outline of the country obtained in that interval appears probable. It is very easy to persuade ourselves that a general very gradual elevation of the country had been long taking place prior to the secondary deposits, and that too accompanied with extensive denudations.

Not only is the inferior gneissose system and the old red sandstone contorted, fractured, and metamorphosed by the intrusion of granite, as we see along the entire coast from Rosemarkie to near Sandwick, and particularly at the Sutors of Cromarty, but also the lias series

* Mr. George Anderson has observed, that "In the finely serrated mountain-chain of the Maiden-paps in Caithness, the conglomerate rocks rise to a great height; their highest point, Morvheim, reaching the elevation of 3500 feet above the level of the sea, and overlooking all the primary rocks of the district." (Guide to the Highlands and Islands of Scotland, 1st Ed. p. 190.)

has been elevated by it, as we learn at the Eathie burn; and the oolitic beds have been shattered, as seen near the Ord of Caithness*. Hence we must date the formation of at least the ridges in which these appearances are presented, at the close of the oolitic period. But one of such ridges is that which runs (with occasional cross fractures) along the entire north-western side of the Great Glen, rising to its greatest height in Mealfourvonie. A very cursory inspection of the district leads us therefore to infer the time of the formation of the Caledonian Valley to have been subsequent to the deposit of the oolitic series; and if we might venture on the idea that outbursts of igneous rocks of a particular character (as for instance granite), within not very extensive areas, were synchronous or nearly so, the extent and position of this fracture lead to the conjecture, that to this later date we must assign the ultimate elevation of the Grampians, and the more striking physical outlines of the Highlands of Scotland.

It is still further clear that great denudation of the country has taken place at a subsequent period. The faults produced by the intrusion of this granite, amounting, as we have said, in some instances to several hundred feet, have been planed down to a perfect level on each side. This is most distinctly seen in the neighbourhood of the lias beds at the burn of Eathie. The vast remaining masses of the old red conglomerate, capping in horizontal strata several hundred feet in thickness lofty mountains on the western coast, are in reality but the base of the Old Red system, the middle and upper portions having totally disappeared; whilst a great tract of central country has been swept entirely clean of the whole series, upper, middle and lower†. A large portion of the removed mass is no doubt to be found in the boulder-clay and the drift-gravel series; yet I cannot but think that the greater destruction of the strata, the great wear and tear of the country, had taken place during its earlier emergence from the ocean, by the ordinary action of the waves and the atmosphere.

I think the evidence which I shall presently adduce is sufficiently strong to prove that the commencement of the post-pleiocene or glacial epoch was, so far at least as regards the North of England and Scotland, a period of subsidence of the land. The relative level of the sea was probably at its commencement not greatly different from that which now exists. I infer it from the following considerations‡.

The groovings and scratchings of the rocks *under* the boulder-clay,

* "The granite of this coast must have been elevated at a period subsequent to the deposition of the oolitic strata." (Sir R. I. Murchison in Geological Transactions, vol. ii. 2nd series, p. 353.)

† In the less elevated and less exposed districts of Moray, Ross, and Caithness, the upper and middle portions of the Old Red system have been better preserved.

‡ I have been happy in finding my views in this respect agreeing with those of Mr. Hugh Miller, worked out at the same time quite unconnected with each other; and since drawing up this paper, I observe that Mr. Darwin has from other data inferred the same in reference to the glacial deposits of Wales, as Mr. Trimmer has in reference to those of Norfolk. See Quarterly Journal of the Geological Society, Nov. 1848, p. 321.

as well as of the boulders *in* it, is a well-known circumstance, and is in fact characteristic of the formation. A mass of gravel boulders and sand not having these marks, may almost as a certainty be set down in the category of modern raised beaches, or may be looked upon as a re-formation of the true boulder series in those beds, which in previous memoirs I have termed the *drift-gravel*. *The drift-gravel I look upon as having originated in a rising condition of the land; the boulder-clay during a period of subsidence.* Now it appears to me, that this very circumstance of the rocks *in* as well as *under* the boulder-clay being thus grooved and polished, is in itself a strong evidence of subsidence. The grooving must have taken place prior to the covering up of the fundamental rock, and the same must be true of each successive scratched fragment of rock in the superior mass*.

The extremely local character also of the great mass of the boulder-clay series seems to direct to a similar view, and to indicate in many instances the direction of the general drifting current. In a paper read before this Society in February 1846†, I pointed to the fact that the colour of different portions of it, even within a very limited area in the Isle of Man, is different, and attributable to the different colours of the rocks over which the drifting current had passed. Through the kindness of George Kemp, Esq., M.D. of St. Peter's College, Cambridge, I have since more fully had established, by chemical analysis of these boulder-clays of the Isle of Man, the fact of their very local origin‡; and the same fact is equally evident along the shores of the Moray Firth, and determines that the drifting current had a direction generally from west to east; I say a *general* direction, because at any *particular* spot the direction would be necessarily dependent upon the shape and direction of the sounds and straits through which the drifting currents were forced.

For instance, whilst in the immediate neighbourhood of Inverness the current appears to have set along the great Caledonian Valley from S.W. to N.E., we find in the Cromarty Firth the scratchings to be due E. and W., and further north at Braambury Hill, and Brora, as stated by Sir R. I. Murchison, they are from N.W. to S.E.

As respects colour and mineral contents, the same thing is evidenced of the *general* direction of the drifting current. In the neighbourhood of Gamrie, we have fragments of the lias beds of the Moray Firth mixed with the ichthyolite beds of the immediate district: as we advance westward along the coast, we get fragments of the corn-stones and upper beds of the old red sandstone; on the Black Isle

* Mr. Miller with his usual acumen pointed out to me the extreme value of the fact which I had often observed, that the majority of the fragments of rocks in the boulder clay are scratched and furrowed in the direction of *their length*. They were evidently not rolled along loosely in water, in which case they would offer the surface of greatest resistance to the wave, and be scratched diagonally, but pushed along as by an ice-raft grinding heavily over them, and therefore sliding on in the direction of their longer axes.

† Quarterly Journal of the Geological Society, vol. ii. part 1. p. 339.

‡ See my 'Isle of Man, its History,' &c., p. 305.

we have again the deeper red-coloured clays, indicating the vicinity of the lower beds of the same series; thence proceeding westward we get clays of a dirty leaden hue, obtained from the flagstones and fish bed of the middle series; and still further westward we have a return to the red colour, when it is found that the lower old red conglomerate is tilted up and reclines against the flanks of Ben Wyvis.

The *constancy* of this same current through a very lengthened period is a most remarkable fact, and points to one simple agent at work in the transportal of materials during the whole epoch of the sinking and rising again of the land.

There is every evidence that the materials of the drift-gravel platforms, (which I believe to have been in greater part formed out of the older boulder deposit during emergence,) as well as the larger boulders on it, have been carried forward still in the same direction. I am not aware that any of these materials have anywhere been discovered *in situ* to the eastward of their present localities. According to Mr. Anderson's testimony, whose accuracy of observation is most remarkable, masses of a rather peculiar gneiss existing *in situ* near the western shores of Ross-shire, are scattered eastward as far as Tain and Tarbet Ness; and the beautiful red porphyritic granite of Calder and Ardclach, between the rivers Nairn and Findhorn, has been borne eastward as far as Fochabers and Speymouth.

The existence of the gravel terraces to which I have just alluded, is a very valuable evidence of the extent to which *at least* the land has been submerged.

For I think there is little reason why we should not attribute to one and the same cause the terraces occurring along the Great Glen, and in those which branch out of it, as Glen Spean, Glen Gloy and Glen Roy, at all the various elevations at which they have been noted. Now we have evidence that the most distinctly-marked terrace of the Great Glen (that which in fact forms its summit-level or watershed at a height of about 100 feet above the present high-water mark) is the remains of a sea-bottom. This remarkable terrace commences at Laggan, betwixt Loch Oich and Loch Lochy; thence it runs along on either side of the Glen in the direction of the Moray Firth. On the western side we find fragments of it, wherever a resting-place is admitted by the otherwise precipitous wall of the valley. It courses round by Clacknaharry into the Beauly Firth; here we see it as a distinct fringe running far up into the country, and after a circuit of about thirty miles, returning again on the other side of the Firth to the Ord of Kessock. Thence we trace it in patches down the north-western shore of the Moray Firth; it runs into Munlochy Bay, and spreads out into a plateau betwixt Fortrose and Rosemarkie; we follow it into Cromarty Firth, and thence round again into the Dornoch Firth, and along the whole coast of Sutherland to the Ord and bluff rocky shores of Caithness. It is however on the south-eastern side of the Moray Firth that its true character as an ancient sea-bottom is more distinctly developed. In the neighbourhood of Inverness, where the great valley begins to open out, and the hills of the old red sandstone recede further into the country, it

spreads out into a fine terrace rising from a cliff of 90 feet fronting the river Ness, to about 115 feet a mile and a half inland, in the neighbourhood of Drakies. We have it thence spreading out eastward by Culloden House into the extensive plains of Nairn and Morayshire. I can hardly help regarding it as identical in age with the great drift-gravel platform which I have mentioned as in the Isle of Man occupying a large space in the southern and central valleys of the island. It seems to me to be a fragment of that sea-bottom, which, when upheaved, united the British Isles with each other and with the continent of Europe, and which has not since been submerged, but gradually eaten away by oceanic currents acting through a very lengthened period. The erosion has proceeded to an extent greater than that indicated by the present outline of our coasts, having been stopped by another elevatory movement of the land. This appears to be indicated by the cliffs of this drift-gravel, often far inland, but almost always found at the opening of estuaries, or where arms of the sea run up into the country, having at their bases extensive raised beaches of a more recent period. We have such a lower sea-beach very distinctly developed along the Moray Firth. In the immediate neighbourhood of Inverness it spreads out into a terrace of many thousand acres, and the lower town is built upon it at an elevation of from twelve to fifteen feet above the present high-water mark.

It is evident therefore that when the depression of the land was to the extent of 100 feet and upwards compared with the present sea-level, the entire Caledonian Valley formed a narrow strait insulating all the counties to the north of it. As the land rose, the passage of waters through this strait would be interrupted, and other circumstances would operate in the formation of terraces at lower levels, such as the draining of the lochs and the deposit of alluvial deltas at the mouths of rivers. In fact, as soon as the communication was cut off in this direction between the seas of the eastern and western sides of Scotland, an extended plateau was originated whose superior limit would be coincident with the present summit-level of the Caledonian Canal, and it would immediately become subject to a variety of destructive agents, which would leave it in patches on each side of narrow valleys, or cut up by river-courses in the more open country.

Hence, again, if we consider the depression of the land to have been to the extent of 1200 instead of 100 feet, and then that gradually the land rose again, we have plainly all the conditions requisite for the formation of such still more elevated terraces as those which occur in Glen Roy.

And hence again, inversely, we may regard such terraces as these as gauges of the depth of submergence to which our Scottish mountains were *at least* submitted.

An important inquiry still remains, viz. to what are we to attribute the great current which seems, through so long a period, to have been flowing over the face of the Highlands in an easterly direction? The answer will probably involve the phænomena of the distribution of erratics in other portions of the British Isles.

Professor Forbes has made a remark, which appears to me to bear upon this question. "The phænomena of the glacial formations," he

observes, "the peculiarities in the distribution of the animals of the glacial epoch, and in the relations of the existing fauna and flora of Greenland, Iceland and Northern Europe, are such as strongly to impress upon my mind that the close of the glacial epoch was marked by the gradual submergence of some great northern land*." Now it is evident that such a continent or extension of land must not only have given a more arctic character to the climate of Great Britain, but also have had the effect of deflecting upon the north-western shores of the British Isles the full power of any currents from the north and west. It is easy to imagine such a distribution of the land on the American continent, and such a change in the sea-bottom intervening between it and the British Isles, that the union between the gulf-stream and the great north-polar current which now takes place about latitude 42° north, and longitude 45° west, shall have been at a point much more eastward and northerly. And we may thus account for that remarkable phænomenon noticed by Professor Forbes in the glacial deposits of Great Britain, of a southern fauna passing at once into a boreal one without any intervening more temperate type. What I mean is, that there are now at work natural agencies sufficient to have produced all the phænomena of the boulder-clay and drift-gravel series, if we but allow the probability of a different distribution of the relative proportion of land and water in our northern hemisphere, and a consequent alteration in climate, and in the direction of oceanic currents.

As far as the northern portion of Scotland is concerned, I see no difficulty in accounting for all the phænomena of the glacial deposits on the principles and through the agencies to which I have just alluded. Perhaps they are capable of a still wider application†.

The conclusions to which my examination hitherto of the phænomena connected with the newer pleiocene gravels, sands and clays, has led me, may be thus briefly summed up; viz.

That at the commencement of the period of the boulder-clay, the relative level of the sea and land in the British Isles was not *greatly* different from what it now is, and that the main features of the country had been already assumed.

That a great current, originating probably in the union of a north-polar current with a modification of the present gulf-stream, was constantly setting in upon the northern and western shores of Great Britain and Ireland, with a climate of an arctic or subarctic character.

That a gradual submergence of the area of the British Isles took place to the extent, in some parts, of at least 1600 feet, and subsequently a gradual emergence of the same extent.

That the *former* event is chronicled by the scratched rocks and boulders of the true boulder-clay series; the *latter* is marked by the more elevated terraces or lower extended platforms of *rolled* boulders and gravel, which are in many instances a redistribution in great part of the materials of the boulder-clay, sometimes regularly stratified.

That during the uprising the more rigorous conditions of the

* Memoirs of the Geological Survey of Great Britain, vol. i. p. 399.

† These views are not supposed to exclude the action of glaciers during the same period.

climate were modified, and erratics from more distant localities were dropped, upon the grounding and deliquescence of icebergs, whilst the scratching and grooving action of littoral ice in a great measure ceased.

That the upheaval of the great terrace, which in the neighbourhood of Inverness rises from 90 to 120 feet above the sea, and from 30 to 130 feet on the east and west coasts of Great Britain and the Isle of Man, marks the period of the last great change in the physical conditions of the country during the glacial epoch.

That after this upheaval and the consequent union of the British Isles with each other and with the continent of Europe, the sea has, through a vastly lengthened period, quietly eaten back its way into the drift-gravel platform, and again separated these countries.

This might be accompanied with a gradual depression again to a certain extent, so that the forests which had grown upon the lower alluvial grounds and valleys, cut out of the drift-gravel, were submerged.

This depression, as indicated by inland cliffs and water-worn caves, was probably to the extent of from 15 to 20 feet compared with the present high-water level, so that a subsequent elevation has left in sheltered situations a low line of beach rising from the present sea-level to the base of the pleistocene cliffs inland, often forming rich alluvial tracts on what were formerly the sands of wider estuaries.

May 2, 1849.

His Royal Highness Prince Albert, K.G., Samuel Blackwell, Esq., and Ebenezer Rogers, Esq., C.E., were elected Fellows of the Society.

The following communications were then read:—

1. *Remarks on* Sigillaria *and some Spores found imbedded in the inside of its Roots.* By E. W. Binney, Esq.

[Communicated by the President.]

Although Stigmaria may now be unquestionably taken to be the root of Sigillaria, still so little is yet known with respect to the latter plant, that every fact in any way calculated to throw light on its history is worthy of being brought before the public. Many new facts are wanted to support or overturn the numerous hypotheses which have been advanced as to the nature of this singular plant and the situation in which it grew.

In seams of coal, as all persons who have carefully examined them well know, there are frequently found remains of common coal plants, such as Sigillariæ, Lepidodendra, Calamites and others. In a paper by me read before the British Association at Manchester in 1842, this circumstance was particularly alluded to as occurring in the Great Lancashire coal-field. They are generally found in the upper portion of the seam, and for the most part appear merely as impressions on the coal.

In the present communication it is intended to show the occur-

rence of Stigmaria *in a seam of coal*, not compressed and bituminized, but exhibiting its vascular system perfectly preserved in iron pyrites, and that portion of the plant which was formerly filled with cellular tissue converted into clay ironstone full of small spores, resembling the spores of the Lepidodendron, as described by Dr. Joseph Hooker in his valuable communication on Lepidodendron lately published in vol. ii. of the 'Memoirs of the Geological Survey of Great Britain.'

The seam of coal known by the name of the King coal at Wigan is a compound one, consisting of several distinct beds parted by deposits of clay. It there lies immediately under the celebrated bed of Cannel, so well known from its value in the manufacture of gas. Now, although the Cannel is very free from pyrites, the King coal is not so, but contains in the midst of it many large lumps, well known among colliers by the name of "brasses." These have to be picked out of the coal before it is sent to market. My observations on these "brasses" have chiefly been made at the pits of the Ince Hall Coal and Cannel Company near Wigan, in whose works great attention is paid to picking them out of the King coal. Having heard that they did not decompose so freely as those found in other mines, I was induced to examine them closely, so as to ascertain the cause of this difference, and I then found that after breaking away the iron pyrites with which they were surrounded, I nearly always came to a Stigmaria very much compressed, composed of clay ironstone.

In the course of my researches I met with two brasses containing Stigmariæ, round and apparently in the original form, without having been subjected to much pressure. Observing a small axis of vascular tissue highly pyritized in one of them, I broke it in pieces and took part of it home with me. On more careful examination of this specimen (fig. 2) some time afterwards, I found the ironstone surrounding the vascular tissue and occupying the space betwixt the latter and the outside of the specimen, full of little bodies about the size of a common pin's head. At first I did not know the nature of these, except that they appeared to be like some kind of seeds; but on carefully comparing them with the spores of Lepidostrobi figured in plates 5, 6, 8 and 10, in part 2, vol. ii. of the 'Memoirs of the Geological Survey of Great Britain,' I became acquainted with their true nature, and from their resemblance I am now led to believe them to be the spores of *Lepidostrobus ornatus*.

Good round specimens of Stigmaria are seldom met with in coal-measures in comparison to those found flattened. Wherever I have met with the former *in situ*, I have found them considerably inclined to the original planes of deposition of the strata, seldom less than at an angle of 15° to 20°; in fact, striking down into the soil in which they formerly grew, and not running horizontally in it. This circumstance is easily explained when we consider how the interior substance of the root has been removed. In the first-named specimens the interior would be decomposed and all removed with the exception of the vascular tissue, and in some cases that portion of the plant as well, without much pressure being exerted against the bark com-

posing the sides, so as to allow a mould to be made, which has been subsequently filled with soft mud, now forming the ironstone, from above. But if the roots were lying level, on their decomposition, the pressure of the mud and vegetable matter placed over them, being much greater than in the first instance, would press down the moulds and flatten them. Effects similar to those above described have taken place in the specimens both round and flattened found lying in the King coal.

The vascular axes of Stigmariæ vary much in their size, and do not appear to increase in proportion to the diameter of the root, for they are often larger in small specimens than in those of greater dimensions. Fig. 1* represents the natural size of a Stigmaria in pyrites in my possession, about $1\frac{3}{4}$ inch in diameter, having its vascular tissue $\frac{4}{10}$ths of an inch in breadth, whilst in fig. 2, the specimen from the King coal, this axis is only a little more than $\frac{1}{10}$th of an inch, although the diameter of the root was about $2\frac{3}{4}$ inches.

Fig. 1.

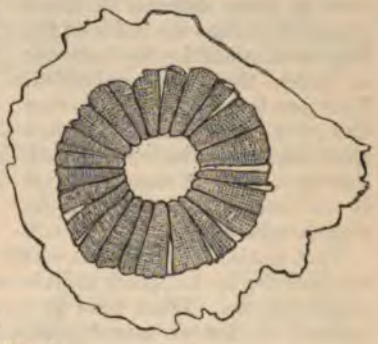

Fig. 2.

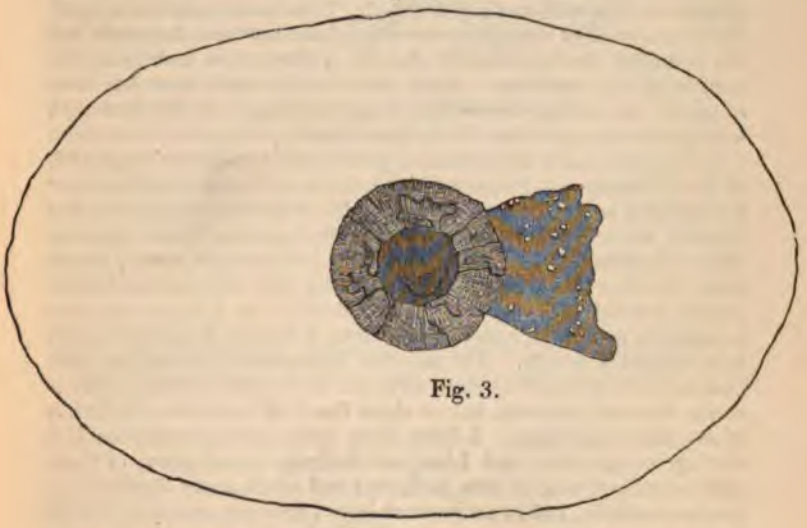

Fig. 3.

* This specimen I procured from Mr. W. C. Williamson, of Manchester, in exchange for another. It was found, I believe, in the neighbourhood of Ashton-under-Lyne.

Fig. 2 shows the last-described specimen of Stigmaria of the natural size, as it appeared when it was first cleared from its covering of pyrites; Fig. 3 the central axis in its proper position, but magnified twice. The small unshaded dots represent the detached spores found equally scattered throughout the whole mass of the clay ironstone forming the portion of the specimen between the vascular axis and the bark. The central part formerly occupied by the pith is also composed of clay ironstone, mixed with a little white spar. The vascular axis, like the exterior of the fossil, is formed of iron pyrites, showing the structure most beautifully.

Fig. 4 represents the opposite sides of three different detached spores taken from the inside of the Stigmaria, out of the clay ironstone in which they were imbedded. They are larger than the average size of the specimens found, and show the raised divisions more distinctly. Each of these drawings is ten times the diameter of the original specimen.

Fig. 4.

That part of the Stigmaria which intervened between the vascular axis and the bark appears to have consisted of two different kinds of cellular tissue. These have in most cases been unfortunately destroyed, so that we cannot positively know their true nature; but they appear to have been of different characters, for there generally appears to be a well-marked division. This is often shown in specimens composed of clay ironstone which have not been flattened, and the boundary line is generally about a quarter of an inch from the outside of the specimen. Most probably the outer zone has been composed of stronger tissue than the inner one, as is the case with well-preserved specimens of Lepidodendron.

In my first paper on Stigmaria, published in vol. xxiv. page 165, of the 'Philosophical Magazine,' I alluded to something like a tap root having been seen, in the following words: "Immediately under, but I could not see it join the tree, proceeded a stem like a tap root, about 2½ inches in diameter, inclining a little to the north; it was about two feet long, but owing to my being able only to examine the mould, I could not make out its characters." As I could not trace its absolute connexion with the tree above, I thought it possibly might be a Calamites *in situ*. The late Mr. Bowman and myself carefully examined the Dixon Fold fossil trees for the express purpose of discovering tap roots to them, but we there found no satisfactory evidence of any such appendage. I have since seen, in the Pemberton Hill cutting on the Bury and Liverpool Railway, many stems of Calamites standing erect *in situ*, both over and under many Sigillariæ in similar positions, but in no instance have I seen any example of what I could consider a true tap root to Sigillaria.

The crucial sutures on the base of Sigillaria alluded to by Dr. J. Hooker, at page 417, vol. ii. of the 'Memoirs of the Geological Sur-

vey,' are not always to be found on specimens. The best examples which I have seen of these extraordinary characters, are two fossils in the museum of the Leeds Philosophical Society. These I first observed in company with the late Mr. Bowman in 1839, when we were both much struck with their appearance, and that gentleman procured drawings of them, of which the present are reduced copies. The specimens are composed of a fine-grained sandstone, and I believe they were found in the coal-measures near Bradford, Yorkshire.

Figs. 5 and 6 represent an under and a side view of the larger of these fossils. The greatest breadth measured across the suture is 2 feet 2 inches. The parts of the roots remaining are mere stumps, and show no true characters of either Sigillaria or Stigmaria, but are marked with the irregular lines so generally found on decorticated specimens of large Sigillariæ, just like those on the Dixon Fold and St. Helen's trees.

Fig. 5.

Fig. 6.

Figs. 7 and 8 represent the under and side views of the smaller of these specimens. The greatest breadth at the base across the suture is 14 inches. As part of the roots of this specimen remain, we see the same system of dichotomizing which was noticed in the Dixon Fold and St. Helen's trees. At the extremities of both roots are the usual areolæ with a little elevation in the centre and the convex corrugated lines so common to Stigmariæ.

Fig. 7.

Fig. 8.

Fig. 9 gives a tolerable idea of the appearances which in my opinion prove the specimen without doubt to be a Sigillaria.

Fig. 9.

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2. *On the Microscopic Structure of* NUMMULINA, ORBITOLITES, *and* ORBITOIDES. By WILLIAM B. CARPENTER, M.D., F.R.S., F.G.S.

ABOUT five years since, I was requested by my friend Mr. S. P. Pratt to endeavour to determine by microscopic examination the character of certain discoidal bodies, varying from about four to ten lines in diameter, which he had found in great abundance in the nummulitic deposits of Biaritz, and the nature of which could not be resolved by any ordinary means. Their circular form and limited dimensions seemed to indicate their relation either to the group of *Nummulites*

or to that of *Orbitolites*. As they did not present any obvious trace of the chambered interior of the former tribe, they had been referred to the latter, notwithstanding the absence of visible pores on the surface and margins; and had been figured by M. Michelin, in his 'Iconographie Palæontologique,' under the designation of *Orbitolites Prattii*, and by M. D'Archiac as *O. submedia*.

Applying to this fossil the same method of investigation with that which had been so successfully employed in the case of teeth, bones, and shells, I was soon able to bring to light its whole interior structure, which, in most specimens, is remarkably well preserved, in spite of its very unpromising external aspect. I found this structure entirely different, however, from anything with which I was at that time acquainted; and having brought it under the observation of many distinguished naturalists and palæontologists, among whom I may mention Professors Ehrenberg and Milne-Edwards, I found them equally unable to assign the place of this body in the animal series, some of them even inclining to the opinion that its nature is vegetable. With the view of throwing light upon this question, I entered upon a more careful examination than had been previously made, into the minute structure of *Nummulites* and *Orbitolites*; and as many of the results which I have thus obtained appear to me to be both novel and interesting, I trust that an account of them may not be unacceptable to the Geological Society. In the course of these inquiries, I have been led to include the new genus *Orbitoides*, established by M. D'Orbigny for the reception of the so-called *Nummulites Mantelli* and allied species*; and it will be seen that my results fully confirm the propriety of the institution of this genus, for which they afford very positive characters; whilst they bring into it Mr. Pratt's problematical fossil, together with several others which had been previously considered as Nummulites.

Nummulina.

My inquiries into the minute structure of Nummulites have been principally carried on upon the *Nummulina lævigata* (Lamarck) of the London clay formation; both as being the species most easily procured, and also as being generally in a condition remarkably well adapted for minute examination. The Nummulites from a calcareous matrix have generally undergone a considerable change in the process of fossilization; their chambers and passages being entirely filled up by calcareous infiltration, and the texture of the shell itself being usually so altered, as to give very little indication of its original character. In a large proportion of the Nummulites from Bracklesham Bay, on the other hand, the clayey nature of the matrix has preserved the shells almost unchanged, and the chambers are usually free from infiltration. Such specimens are obviously the best adapted, therefore, to afford indications of the original characters of the shell, and also of the animal, or assemblage of animals, to which it served as a protection.

* Quarterly Journal of the Geological Society, vol. iv. p. 12.

My examinations, it will be as well to state, have been made in two ways; first, by making *sections* thin enough to be viewed with a high power by transmitted light; and second, by breaking the shell in various modes, and examining by reflected light the parts laid open by the *fracture*. Both of these methods are necessary, in order to gain a satisfactory idea of the complicated arrangement of which I shall now proceed to give an account; since each affords information which the other is unable to yield; and the errors into which we might be led by the inspection of one set of appearances, are corrected by those presented by the other*.

When we have made a horizontal division of *N. lævigata*, either by section or fracture, through the medial plane (*a a'*, fig. 4, Pl. III.), a cursory inspection may satisfy us that the character of its spire, and the form and arrangement of its chambers (fig. 2), are very different from those of the chambered shells of the Cephalopodous Mollusks. The increase in the breadth of the spire in successive whorls, though tolerably regular at first, becomes afterwards very slow, and seems to cease altogether; and it not unfrequently happens that a spire enlarges rather suddenly, as at *a*, or that a large part of one spire (as that marked *c*) is narrower than those on its interior and exterior (*b* and *d*). The division into chambers, also, is far from being regular, the distance of the septa from each other being subject to great variation even in the same whorl; and cells much smaller than the rest, and apparently *abortive*, being not unfrequently seen, as at *e*, fig. 2, and at *a* and *b*, fig. 3. In specimens whose chambers have been filled by calcareous infiltration, it not unfrequently happens that the central portion of this is deeply tinged, in every chamber, with dark brown matter, which has every appearance of being the residue of some organic substance. These facts are important, as tending to show that the animal of Nummulite must have borne a resemblance to that of the existing Foraminifera, and have been composed rather of an aggregate than of a single body.

This inference is confirmed by an examination of the septa which divide the chambers, under a higher magnifying power. For it then appears that each of these septa is *double*, so that every chamber has its own proper wall; and further, that there is a space between the two layers, which, being filled up with crystalline infiltration in the fossil Nummulite, must have been vacant in the recent shell, unless occupied by the soft parts of the animal itself. This, which may be termed the *interseptal space*, is well seen in several of the septa whose broken edges are delineated in fig. 3. That each septum is perforated by an aperture, close to its junction with the margin of the pre-

* It appears to be from having followed only the second of the above methods, that MM. Joly and Leymerie, who have recently been giving their attention to the same subject with myself, have arrived at results which will prove, I believe, to be in some respects erroneous and in others imperfect. As my investigations have been pursued quite independently of theirs, I think it better not to interrupt my account of them by continual references to the memoir of MM. Joly and Leymerie (Mém. de l'Acad. des Sciences de Toulouse); but shall confine my notice of their labours to a brief indication of those points in which their results coincide with my own, or in which they differ from them.

ceding whorl, was first stated, I believe, by M. D'Orbigny (Annales des Sciences Naturelles, 1826, tome vii. p. 295). This aperture, which was correctly figured—I believe for the first time—by Mr. Sowerby (Mineral Conchology, vol. vi. p. 73. tab. 538), is best brought into view by fracturing a Nummulite in a direction perpendicular to that of the preceding sections, so as to present a broken edge, of which about one-half is shown in fig. 4. On looking into the chambers which are thus laid open, along the line *a a'*, we are of course stopped by the septa *b*, *b*, each of which is seen to present an aperture *c*, *c*, where it abuts against the margin of the preceding whorl. From the examination of specimens fractured in various directions, I am quite satisfied that these perforations pass through *both* layers of each septum, so as to establish a free communication between one chamber and another. The case is different, however, with regard to certain more minute apertures, (not discerned, I believe, by any previous observer,) which may be seen, by a careful examination under a sufficient magnifying power, to exist on the surface of every septum, though not constant either in number or position (see fig. 7, *a*). I at first believed that these also pass from chamber to chamber; but I am now satisfied that they penetrate that layer *only* of the septum, on whose surface they open, and that they really establish a communication between each chamber and the adjoining interseptal spaces. Other apertures of the same kind may be generally traced, on careful examination, in those walls of the chambers that form the surface of the whorl; and these, too, appear to communicate with the interseptal spaces, by channels burrowed in those walls, as shown in the lower part of fig. 6, and also in fig. 16, in which last they are represented as seen in a thin section of the roof of the chambers.

Thus the cavity of each chamber communicates with that of the one before and behind it in the same whorl, by the large aperture first mentioned, which frequently appears as if made up by the coalescence of a number of smaller perforations (fig. 7, *b*), suggesting the idea that the animal substance which originally passed through it was not a single large canal, but was composed of a bundle of minuter tubes or threads. This idea is confirmed by the circumstance, that the outer margin of the included whorl (fig. 7, *c*) frequently presents a series of furrows, corresponding to the notches at the inner edge of the septum (*b*). Each cavity also communicates freely with the interseptal spaces on either side, by the smaller apertures and passages last described; and from this space, as we shall presently see, there was a free passage to the external surface of the shell.

The texture of the shell itself differs remarkably from that of any of the Mollusca with which I am acquainted, approaching that which I have described in the common Crab (Reports of the British Association, 1847, p. 129). It is everywhere perforated by a series of tubes of extreme minuteness, which pass directly from one surface to the other, their openings being plainly visible on each (fig. 16). The diameter of these tubes is about 1-7500th of an inch; and their

distance from each other about 1-15,000th. In a thin vertical section of the shell (fig. 15) they are seen to run parallel to each other, and to be free from sinuosities or interruptions. The whole of this portion of the shell, therefore, is minutely porous. The structure in question can seldom be clearly distinguished in those Nummulites which have had their texture altered by calcareous or siliceous infiltration; but as the appearances which these present correspond closely with those exhibited by specimens of *N. lævigata* which have been subjected to the same change, I have no doubt that the tubular structure in question is common to the whole group. Very frequently the metamorphosis is such as to give the appearance of a minute prismatic arrangement to the shell-substance (as shown transversely in fig. 12, *b*, *b*), by which I was myself deceived until I had examined specimens in which less alteration had taken place. All the Nummulites which I have examined present a remarkable departure from this structure, in that portion of the shell which forms the *margin* of each whorl. Here, instead of an assemblage of minute, closely-set, parallel tubuli, we have a much coarser arrangement, the solid substance being perforated with a smaller number of tubes of two or three times the diameter of those last mentioned, which pass in a radiating manner from the inner to the outer surface. Some indications of this difference are seen in fig. 4; but it is much more clearly displayed at *b*, *b*, fig. 15, which represents a portion of a very thin section taken in the same direction, and viewed by transmitted light. The openings of these tubes on the outer margin of the whorl are not readily discernible, partly in consequence of the somewhat oblique direction of the orifices, and partly through these being usually covered with a calcareous incrustation. When this has been removed by the application of dilute acid, they are easily seen when properly looked for, as was first pointed out to me by Mr. J. Morris.

Each successive whorl of the Nummulite, as is well known, not merely surrounds the preceding whorl, but completely invests it; so that, in a vertical section, each chamber of the medial plane is seen to be covered with as many layers of shell above and below its own roof and floor, as there are chambers intervening between it and the nearest margin of the section. Thus in fig. 4, the chamber *d* has three chambers on its exterior, and is invested by three layers of shell above and below, in addition to those by which it is itself inclosed. On the other hand, the chamber *e*, which is the tenth from the margin,—that is, which has nine whorls on its exterior,—is invested by nine layers above and below. In some species of Nummulites, as the *N. complanata*, these investing layers are closely applied to each other, over the whole of each surface; the chambers only occupying the margin of the whorl, as shown in fig. 17. But in by far the greater number of species, these successive layers are not in contact with each other, being separated by prolongations of the marginal chambers, which extend over the entire surface of the disk. These chambers are still divided by prolongations of the marginal septa, which are continued between the investing portions of the contiguous whorls, and form a series of vertical partitions, upon which the successive

layers rest. This is shown in fig. 4; in which we see at *f*, *f*, *f*, the three outer investing layers; at *g*, *g*, the two spaces intervening between them, which are prolonged from the marginal chambers; and at *h*, *h*, *h*, the vertical partitions, prolonged from the marginal septa, by which these successive layers are supported one upon another. In general these partitions tend with greater or less regularity towards the centre of the disk; but this is not the case in *N. lævigata*, for here they run a sinuous and inconstant course, sometimes inosculating, and again diverging, so as to divide the whole surface of the disk into a number of irregular areæ. The origin of these partitions from the septa of the marginal chambers, and the character of their subsequent course, are seen in fig. 3; at the left hand are shown portions of three whorls which are laid open through the medial plane; whilst on the right are seen the investing portions of two of these, with the broken edges of the partitions formed by prolongations of the marginal septa. A larger portion of one whorl, showing the continuity of the septa and chambers in its *marginal* and *investing* portions, is shown in fig. 6. As the course of these partitions is a very strongly-marked feature in the structure of Nummulites, and presents many very obvious differences, I am inclined to think that from such differences valuable specific characters may be obtained.

I have now to describe one of the most curious, and until recently unsuspected features in the structure of Nummulites;—I allude to the existence of a series of perforations of considerable size, which pass directly downwards from the exterior, through the superposed investing layers of the successive whorls, however numerous, until they reach the roof and floor of the chambers of the central plane, which they do *not* penetrate. Various observers had remarked *punctations* on the surface of certain species of Nummulites; these being sometimes elevations and sometimes depressions. I believe that MM. Joly and Leymerie were the first to surmise that these punctations are in reality the mouths of passages, which are blocked up by the infiltration of mineral matter subsequently to the death of the animal, and that their occasional projection from the surface is to be attributed merely to the superior hardness of the matter that fills them (which forms the 'columns' or pillars of Mr. Sowerby, *loc. cit.*), and to the slight abrasion of the shell around them. Guided by the analogous characters presented by the indubitable perforations in the shells of fossil Terebratulæ, I had myself arrived at the same conclusion, before I became acquainted with the researches of MM. Joly and Leymerie; having found that the substance with which these perforations and passages are filled, evidently differs altogether from the texture of the shell itself, and presents all the characters of a calcareous infiltration. In fig. 1 is represented a thin section taken nearly parallel to the surface, so as to pass nearly in the plane of some of the investing layers; the dark portion represents the shelly texture already described; the irregular light spaces on the middle and left of the figure, are the lacunæ filled with calcareous infiltration; whilst at the right, some of the chambers of the medial plane are laid open. These passages may be frequently seen, in a piece like

fig. 8 obtained by a vertical fracture, passing from the outer surfaces towards the medial plane, in a somewhat conical form, contracting as they descend; but they are never directly traceable into the chambers of the central plane. MM. Joly and Leymerie do not appear to have determined their mode of connection with these chambers; although in their ideal figure of the animal of Nummulite (fig. 5), they represent pseudopodia passing out, it must be supposed, through such apertures. I have satisfied myself, however, by a careful examination of numerous specimens, that they always terminate *over the septa* (as shown in fig. 8), and actually pass *into the interseptal spaces*, which we have already seen to have numerous communications with the chambers themselves. I am confirmed in this view, by finding that wherever they penetrate the investing layer of any whorl, the perforations pass between the two laminæ of the prolongations of the septa, which are double along their whole course (as may be seen in fig. 6). These laminæ diverge to give them passage (*a*, *a*), and then reunite, thus completely enclosing them, and cutting them off from the vacant spaces between the investing whorls. Thus a direct and continuous tubular connection is formed between the interseptal spaces of the central plane, and the external surface of the shell; and as these spaces are connected, by numerous small apertures in the septa, with the chambers between which they are interposed, we see that no chamber, however deeply buried beneath the investing whorls, is cut off from communication with the medium inhabited by the animal. In the *Nummulina complanata* (fig. 17) and other species, in which every investing whorl is in contact with the one it incloses, except at its edge, the perforations have the form of *fissures*, that correspond with the subjacent septa, towards which they directly pass. These fissures are usually found to be filled with opake matter; and the dark bands thus formed in a transparent section (fig. 12, *a*, *a*) are seen to be crossed by delicate white lines, which seem to indicate a division of the fissure into a number of tubes of irregular form,—probably for the passage of pseudopodia.

All my observations tend, therefore, to confirm the opinion generally entertained, that the *Nummulites* are members of the group of *Foraminifera*; and that each chamber may have been tenanted at the same time by a living segment, connected with those before and behind it by means of one or more tubular prolongations, and absorbing its nourishment from without by means of filamentous pseudopodia projecting through the system of passages leading from the medial plane to the external surface. Every whorl, as we have seen, retains its connection with the exterior by means of the vertical passages; and as we do not find those of the inner whorls blocked up by the investing layers of the outer, but as, on the contrary, they are invariably continued through them, the inference appears to be justified, that the segments of the animal inhabiting the chambers of the inner whorls did not lose their vitality when thus more deeply inclosed. It will obviously be only from the *outer* whorl, however, that the *marginal* pseudopodia can issue; and this would give to *those* segments an advantage which we may not unreasonably suppose them

to have possessed, as it is by their agency that the growth of the shell is continued by the addition of new whorls.

There is a very striking conformity between the structure of the shell of Nummulites and that of *Polystomella crispa*, of which an elaborate description has recently been given by my friend Mr. W. C. Williamson (Transactions of the Microscopical Society, vol. ii. p. 159 *et seq.*). I would especially call attention to the following points of correspondence. Mr. W. states that, after a variety of examinations, he has satisfied himself "that each septum separating two cells, consists of a double calcareous layer, the soft inhabitant of each shell secreting its own share." He has noticed, like myself, irregularities in the growth of the shell, which are totally inconsistent with the idea of its having been formed by a single body in continuous growth, like that of the testaceous Cephalopoda. "Sometimes," he says, "the cells continue gradually to increase in size with symmetrical uniformity, when suddenly one of them is found to be arrested in its development, not attaining to half its proper dimensions; and the new ones subsequently added, are regulated in their increase of size, not by those which had previously attained to their full development, but by the one which has been so stunted, from the contracted form of which, the cells again continue to grow and increase in regular order; only being thrown back, as regards their size, by almost an entire convolution." Of the contained animal itself, which he obtained by dissolving away the calcareous matter of the shell with dilute acid, Mr. Williamson says, that it consisted "of a very thin external membrane filled with gelatinous matter." "No trace of minute internal organization, such as a specially located intestinal canal, or ovaries, could be detected" by Mr. W.; nor was he able in any instance "to discover with certainty the presence of any foreign bodies in their interior." The several segments are described by him as connected by a series of prolongations, which pass through the septa near their inner margins. The segments at first formed have only single connecting necks; but the number of these soon increases, and the outer segments are connected by ten or more such necks, which pass through as many distinct orifices in the septa. If all these orifices were brought together on the central plane, so as to coalesce into one, they would exactly correspond with the single perforations in the septa of Nummulites. The animal of Polystomella is considered by Mr. Williamson to derive its nutriment from pseudopodia, which are projected through numerous minute apertures over the whole surface of the shell. He has not clearly traced these pseudopodia, however, into connection with the segments occupying the interior whorls, which, like those of Nummulites, are invested by those of later formation; but he mentions (as Ehrenberg had done), that near the umbilicus they are projected in fasciculi; and he states that the surface of the central calcareous nucleus (which is formed by a thickening of the walls of the smallest cells) is pitted by small but deep depressions, which may be designed to facilitate the exit of the pseudopodia from the innermost convolutions. Mr. Williamson goes on to point out, that to these pseudopodia must be attributed

the deposition of new matter upon that portion of the central nucleus which is not covered by the investing whorls; and in this view he is in accordance with M. D'Orbigny, who, in his recent work 'Sur les Foraminifères Fossiles du Bassin Tertiaire de Vienne,' fully recognizes the power of the pseudopodia to secrete the calcareous covering. I may remark, that I cannot see how the investing layers covering the disk of *Nummulites complanata*, and the other species of the same group, can be formed in any other way; since, in these, the chambers are only marginal, the segments of the animal not extending over the disk; and we have no reason to believe in the existence of any external mantle, spreading over the whole surface, whereby these investing layers could be formed.

It is worthy of remark, that, in the outer whorls, the two laminæ of the septa diverge from each other, as in Nummulites, where they join the outer margin of the chamber; and that they thus leave an interseptal space, towards which certain prolongations of the animal structure appear to pass. If it should be found that the pseudopodia arise from these, the resemblance of the animal of *Polystomella crispa* to that by which the shell of Nummulite was probably formed, would seem to be very close.

The view which we take of the *individuality* of the segments of the animal of Nummulite, must depend upon the ideas we entertain regarding the nature of similar aggregations in other Foraminifera, as well as in Zoophytes and the inferior Mollusca. The several segments appear to be, in all essential particulars, mere repetitions of each other; they are formed by successive gemmation from a single primordial segment; and when this gemmation has taken place, the newly-formed segment appears to be as independent of the rest, as are the several polypes in a polypidom. There is no indication that the inner and earlier segments derive their nourishment through their connection with the outer and last-formed; on the contrary, there is every indication that the former continue to maintain the same communication with the exterior which they ever had; and that the necks which are prolonged through the apertures in the septa are rather to be considered in the light of *stolons* or creeping stems, from which new gemmæ are to be produced, than as resembling an intestinal canal common to the whole series of segments. We may consider the entire structure, then, either in the light of a series of *distinct individuals* developed by gemmation from the first-formed segment, like the clusters of the compound *Tunicata*; or as a single aggregate being, made up of an assemblage of similar parts indefinitely repeated. It does not seem to me of much consequence to decide between these two views, if we distinctly recognize the essential independence of the segments, and their multiplication by gemmation. This is a matter of some importance in regard to the determination of species; for if we are to consider Nummulites as analogous rather to the *polypidoms* of Zoophytes or Bryozoa, than to the shells of the Mollusca, it is obvious that we must allow for a considerable amount of variation in their form, without any transgression of specific limits. It is well known that many species and

even genera of corals have been founded upon variations in the mode of growth in one and the same species; and I am disposed to believe that the range of variation is almost equally great in some species of Nummulites. I have carefully examined many individuals differing widely in external form, without being able to detect in them any difference in internal structure at all worthy of being accounted a specific character; and this will not be deemed surprising after what I have already stated, respecting the irregularities which may occur in the consecutive chambers of a single whorl. Differences in the proportion between the diameter and thickness of the disk, appear to me to be especially unsatisfactory as specific characters; for I have met with specimens almost lenticular, which could not be discriminated by any other indications from specimens of a nearly globular form. It is obvious that such differences may arise from variations in the thickness of the calcareous deposit; such as are continually seen in the polypidoms of Zoophytes, and in the shells of Mollusca.

Without at present entering in detail upon the question of specific distinctions, I may mention that the genus *Nummulina* appears to me to be divisible in the first instance into two subgenera; of which one shall comprise the species in which the investing whorls are in close apposition with each other, except at their margins, so that the chambers of each whorl surround the preceding, without covering them; whilst in the other, the new chambers are prolonged over those of the preceding whorl, so that the investing whorls of the shell are only connected with each other by the prolongations of the intercameral partitions.

For the further subdivision of these groups, I am disposed to believe that the modes of arrangement of the prolongations of the septa between the contiguous surfaces of the investing whorls, will prove to be a character of great value in addition to those on which reliance is at present placed; as will, also, the disposition of the perforations which I suppose to give exit to the pseudopodia. I may remark, that the genus *Lycophris*, created by Montfort for the reception of certain species in which the superficial punctations caused by these perforations are especially noticeable, cannot be any longer maintained, since my examinations prove, not merely that these perforations are common to Nummulites in general, but that the so-called *Lycophris scabrosus* of Sowerby is nothing else than an ordinary Nummulite, whilst the *Lycophris dispansus* and *Lycophris ephippium* of Sowerby do not belong to this group at all, but are indubitable *Orbitoides*.

Orbitolites.

There can be no doubt, that, under this designation, various objects have been assembled which have no real relationship to each other. My observations have been made upon *Orbitolites complanata* of the Paris basin, and upon a recent species from the Australian seas, very closely allied to it, which is referred to by Prof. E. Forbes (Quarterly Journal of the Geological Society, vol. iv. p. 12) as having been apparently known to Defrance, and as probably the *Marginopora* of

Quoy and Gaimard; and which has been recently brought again under the notice of naturalists by Mr. Jukes, who collected it in considerable numbers. These two agree closely in every particular save the form of the superficial cells, which in the *O. complanata* are nearly round (fig. 30), whilst in the Australian specimen they are oval, or rather almost quadrangular (fig. 29); they must unquestionably be regarded, therefore, as nearly allied species of the same genus; so that, if the *O. complanata* is to be regarded as the fossil type of the genus, the Australian species must be considered as the recent, and the generic term *Marginopora* must be dropped. In *both* we find that the cells of the *surface* are closed, unless laid open by abrasion, and that the only real apertures exist at the *margin*; so that the designation *Marginopora* is really as applicable to the one as to the other.

The structure of the Australian disk, as shown by a thin section parallel to its surface, is delineated in fig. 24, in which the cells are seen to be arranged with great regularity in concentric rows. It is only near the margin of this section (as at *a*, *a*), however, that its plane has passed sufficiently near to the surface, to show the cells in the oval form which they there present; elsewhere the section has traversed a deeper stratum of the coral, in which the cells present a rounded section when cut across. This difference in the form of the cells as they pass down obliquely into the polypidom, is shown on a larger scale in figs. 25 and 26; of which the former represents the oval cells of the surface, laid open by a section passing through their plane, and the latter a corresponding section of the round cells or passages of the interior of the polypidom. Fig. 23 is a section of *O. complanata* taken in the same direction as fig. 26, and exhibiting a slight difference in the arrangement of the partitions, which causes the entire disk to present some resemblance, when thus examined, to the back of an engine-turned watch.

The structure of the interior of the disk, as shown by a vertical section, is exhibited in fig. 27; in which we see the oval cells of the two surfaces, *a*, *a*, divided from each other by regular partitions, and covered-in above by complete opercula; whilst in the intervening portion of the disk, we see nothing but a series of round apertures that seem less regular in their arrangement. If such a section be made close to the margin, we lose the superficial cells, but we bring into view the openings of the deeper rounded cells upon the margin itself, as shown in fig. 28. I am not altogether confident in the correctness of my interpretation of these appearances, which are faithfully represented in the adjoining figures; but I am disposed to believe that if this disk was really formed by an animal or collection of animals of the Bryozoal type, the round passages opening at the margin, and penetrating obliquely into the polypidom, so as to be cut across both in horizontal and vertical sections, constitute the real habitation of the animal; and that the ovate cells, which form so peculiar a layer upon the surface, are a later production, not improbably for the reception of ova. These ovate cells would seem to communicate with the cylindrical passages beneath, by means of two small apertures in each cell, as shown in fig. 25.

Orbitoides.

In adopting the generic name which M. D'Orbigny has conferred upon the fossil previously termed *Nummulites Mantelli* (Quarterly Journal of the Geological Society, vol. iv. p. 12), and in extending it to several other species, of which some had been previously ranked among *Nummulites*, and others among *Orbitolites*, it is proper for me to state that I am unacquainted with the definition of the genus proposed by that distinguished palæontologist, which has not, so far as I am aware, been yet made public. The institution of the genus appears to me to be required for the reception of a number of fossils, which my own inquiries have led me to recognize as presenting a type of structure so dissimilar to that of either of the groups just named, as well as to every other with which I am acquainted, as to render their separate association desirable. My account of the genus will be principally drawn from the species just named; of which, through the kindness of Sir Charles Lyell, I have been enabled to examine many excellent specimens from the nummulitic limestone of Alabama, whilst by the liberality of Sir Roderick Murchison I have had the opportunity of examining specimens of what I have no hesitation in regarding as an *identical species* from the nummulite limestone of Cutch.

The *Orbitoides Mantelli* is a discoidal body, sometimes attaining the diameter of an inch or even more, and having a thickness of about a tenth of an inch near the centre, but gradually thinning away towards the edges. No traces of cells are visible upon its external surface; but when it is split through the medial plane (which is the case with many of Sir Charles Lyell's specimens), the exposed surfaces present a close resemblance to the exterior of an Orbitolite; having numerous cells with rounded or somewhat oval orifices arranged in regular concentric rows, as shown in fig. 31, which represents a small portion of the interior structure disclosed by a fracture which has laid open some of the cells, but has left others with their covers unbroken. The resemblance of the surface of this central layer of cells to that of *Orbitolites complanata* (fig. 30) will be apparent on a comparison of the figures; and there is also a great similarity in the aspect of the cells, when seen in a section parallel to the surface (fig. 21), to that of the cells of the recent Orbitolites of New Holland, when crossed by a section taken in a similar direction (fig. 26). But these resemblances end; for we shall find that both in the structure of the central layer itself, and in the addition of the crust on either surface, which is totally unlike the two layers of ovoidal cells on the exterior of the Australian coral, Orbitoides is extremely different from Orbitolites. These differences are made evident by examining a section of this fossil made perpendicularly to the surface (fig. 20); for we then see that the cells or chambers of the medial plane form but a single layer (*a*, *a*); and that this is covered-in, above and below, by a thick crust (*b*, *b*), which is itself composed, like the shell of Nummulite, of several layers with intervals between them. These layers, however, when carefully examined, are found not to possess the continuity of those formed by the investing whorls of Nummu-

lites; nor do they bear, like these, any numerical relation to the chambers of the central plane. They are most numerous, however, as in Nummulites, over the central portion of the disk, and gradually diminish towards its margin. Their number seems to vary considerably in different specimens whose diameter is about the same. When a thin section is made through these layers, parallel to the surface, the structure brought into view is very different from that of any Nummulite; for we see that it is made up of a number of distinct flattened pieces of irregular form (resembling those of *O. Prattii*, fig. 33), closely fitted together like the cells of the cuticle of an apple-leaf, or the portions of a dissected map. Between the successive layers thus formed, certain thin spaces are left, as shown in fig. 20, which are circumscribed by the adherent margins of the pieces between which they lie; these spaces are not unfrequently occupied, in the Alabama specimens, by an amorphous infiltration, which renders them opake by transmitted light; in the Indian specimens they are filled with calcareous matter in a crystalline state, which has also found its way into the chambers of the central layer.

From the degree of alteration which all these specimens have undergone in the process of fossilization, I am not able to give as complete an account as I could wish of the minuter features of this structure. I am inclined to believe, however, that the several chambers of the central layer communicate with each other by four or more perforations through each septum, which some of my sections appear to me to display. I cannot trace in *this* species any appearance of passages by which the inhabitants of the chambers of the central layer could have communicated with the world without; but I shall presently describe two methods of communication as discernible in *other* species, and I have little doubt that one of them must have existed here.

The structure of *Orbitoides Mantelli* presents on an enlarged scale all the essential features of that which I had previously made out in the (so-called) *Orbitolites Prattii* of Biaritz. A section of the latter fossil taken parallel to the surface, almost always brings into view two distinct structures, as shown in fig. 32; that marked *a*, *a*, and seen upon an enlarged scale in fig. 33, being evidently the representative of the external layers of *Orbitoides Mantelli*; whilst that marked *b*, *b*, and seen as more highly magnified in fig. 34, represents the chambered layer of the last-named species. That such is the true account of it, is clearly indicated by the appearances shown in vertical sections of these disks, a view of which, under a low magnifying power, is given in fig. 35; whilst a small portion of the section, more highly magnified, is shown in fig. 36. That both structures should be almost invariably brought into view by a section made parallel to the surface, is readily accounted for by the circumstance that the disks are seldom or never flat, so that, as they are extremely thin, a plane section intended to pass through one layer must necessarily in some parts traverse the other.

The chambered structure frequently presents considerable irregularities, as seen at *b'*, fig. 32; I am not sure, however, that these are

really so great as they seem, since the apparent interruption of a row of chambers may be due to its passage above or below the plane of the section. In the enlarged representation given in fig. 34, it is shown that the septa that divide the chambers of the same row are in reality double, like the septa of the Nummulite.

When we obtain a very thin section of the investing layers of *O. Prattii*, and submit it to a sufficiently high magnifying power, we see that each division is penetrated by a number of apertures, of nearly the same size and distance from each other as those of the shell of Nummulite (fig. 33). These apertures form a communication, therefore, between the successive spaces that exist between the overlying layers; and in this manner the animals inhabiting the chambers of the medial plane may have drawn in nutriment from the surface. In many of the specimens of this fossil which I have subjected to minute examination, the apertures in question are not visible; in consequence, it would appear, of the changes induced by fossilization. Their apparent absence in the preceding species, therefore, by no means indicates their real deficiency; and as the two species otherwise agree in almost every other respect than in their size and in the form of the chambers of the central layer, I am disposed to believe that the structure in question was common to both.

Among the Biaritz specimens of this fossil are many which are more or less contorted; and some of them are twisted into an ephippial form. These last, however, agree so precisely with the flattest individuals in the characters of their minute structure, whilst the transition from the one to the other seems to be effected by so many intermediate forms, that I think that we can scarcely regard them as specifically distinct. Another specimen in Mr. Pratt's collection, however, appears to have had a very different mode of growth; for instead of being a circumscribed disk, it seems to have spread itself irregularly in every direction, and to have been attached to the surface of rocks, whose contour it has followed, like the Lepralia or any other incrusting Zoophyte. A section of this, taken parallel to the surface, could hardly be distinguished from that represented in fig. 32; but the vertical section (fig. 22) differs in the much greater number of incrusting layers. This might be regarded as merely an indication of greater age; but the absence of definite size and form in the specimens in question appears sufficient to justify their separation as a species distinct from the preceding. In neither case do we find any very definite markings upon the *surface* of the fossil, which might serve as a distinctive character. The aspect of that of *Orbitoides Prattii*, as seen with reflected light under a low magnifying power, is shown in fig. 37. The markings seem to correspond with the divisions shown under a higher power in fig. 33; and I have not been able clearly to trace any large punctations at all similar to those displayed by the group of species I shall presently describe, though I have sometimes suspected their existence.

The resemblance of these bodies to Nummulites is sometimes greater than that which is shown by the preceding specimens. Thus in fig. 18 is shown a section of a small form which I have happened

to cut through in examining a piece of nummulitic limestone. This might be readily mistaken for a Nummulite, upon a cursory examination; but that it does not belong to that group is obvious from the want of numerical correspondence between the number of investing layers and that of the chambers in the central plane, as well as by the want of continuity in the investing layers themselves. And a careful comparison of it with the corresponding section of *Orbitoides Prattii* (fig. 35) will show that it differs from that species in no other important particular, than in the larger relative size and smaller number of the chambers in the central plane.

Among the specimens obtained by Capt. Grant and Capt. Vickary from the nummulitic limestone of North-Western India, and hitherto regarded as Nummulites, I have obtained one, as already stated, which I believe to be identical with the *Orbitoides Mantelli* of North America. But besides this, I have met with four or five other species, which seem to be clearly referable to the same generic type, although differing in certain important particulars. A vertical section of one of these, taken from a species hitherto, I believe, undescribed, is shown in fig. 19; and it is there seen that the central layer of cells bears an extremely small proportion to the entire thickness of the specimen (the edge of which is broken away at its lower part), and that the investing layers present the appearance of being traversed by conical passages, extending from each surface towards the central layer. These passages, being filled up with the opake matter of the matrix, look darker than the surrounding structure of the fossil. The appearance presented by a vertical section of the *Lycophris dispansus* of Sowerby is very nearly the same; and the surface of this body exhibits large punctations, which obviously mark the entrances to these passages. The structure of *Lycophris ephippium* is the same; and it is worthy of notice that its peculiarities had been perceived and delineated by Mr. Sowerby (Geol. Trans. 2nd Ser. vol. v. pl. 24. fig. 15), who describes as *pillars* what are in my apprehension nothing more than the columns of opake matter filling the perforations. In fig. 13 is represented a vertical section, and in fig. 14 a horizontal section passing through the central plane, of an undescribed fossil from Scinde, which obviously belongs to the same genus, although presenting the external aspect of a Nummulite. Its diameter was about an inch, and its thickness about one-fifth of an inch. Here, too, we observe the central layer (*a*, *a*) to be extremely thin in comparison with the layers (*b*, *b*) by which it is invested on either side; and these do not thin away towards the edge, as we see them to do in most other species, but the outer portion of them is prolonged from both surfaces over the margin of the disk, so as to meet (as at *c*) and completely inclose the central layer,—a peculiarity which I have nowhere else seen. I think it not improbable that this may be the adult condition of some of the smaller species. The superficial layers are evidently traversed, as in the preceding cases, by passages now filled with opake matter (*d*, *d*). The chambered layer, as seen in the horizontal section (fig. 14, *a*, *a*), closely corresponds with that of *Orbitoides Prattii* (fig. 32); but the investing layer is distinguished

by the dark spots at the angles of its divisions. These spots are obviously the transverse sections of the passages already described, which are filled with opake matter; they are much larger in sections taken near the external surface, on account of the infundibuliform shape of these canals. In some instances these passages seem to have been very large and open, especially towards the external surface, as is shown in fig. 10, where they are indicated by the dark spots. But in other instances (as shown in fig. 9, *a*, *a*) these spots are divided by lines, which seem like delicate partitions dividing the entire canal into smaller passages. This harmonizes well with the idea that each passage might have given exit to a fasciculus of pseudopodia, like that which we have supposed to issue from the passages in Nummulite, which bear so close a resemblance to those now under consideration.

After a careful survey of the characters presented by the group of fossils I have been describing, I feel strongly inclined to the conclusion that their affinity is rather to the Nummulites than to the Orbitolites, and that the animals which formed them are more likely to have been *Foraminifera* than *Bryozoa*. I cannot see *any* strong point of real resemblance between Orbitoides and Orbitolite, the difference in the position of their respective chambered layers being kept in view; on the other hand, the resemblances between Orbitoides and Nummulite are very close; whilst the differences are by no means so great as those which exist among other members of the singular group of Foraminifera, and which seem chiefly to depend upon variations in the mode of gemmation.

The Foraminiferous character of Orbitoides appears further to be indicated by the presence, in all the species I have examined by sections taken through the centre, of the large globular cavity (fig. 35, *a*), resembling that which is stated by M. D'Orbigny and Mr. Williamson to be the ordinary form of the first segment of the Foraminifera, whatever may be the form which the compound structure may subsequently present.

EXPLANATION OF THE FIGURES. (Plates III. to VIII.)

Fig. 1. Transparent section of *Nummulina lævigata*, nearly parallel to the median plane, passing at the upper part through the marginal portion, and at the lower through the central portion, of one of the investing whorls, and showing the irregular form of the perforations, which are here filled by a crystalline infiltration of carbonate of lime. Magnified 10 diam.

Fig. 2. Transparent section of *Nummulina lævigata*, through the median plane, showing portions of several successive whorls: at *a* is seen a sudden enlargement in the size of the chambers; and at *c* is seen a narrow whorl intervening between two broader ones, *b* and *d*. The chambers are filled by a crystalline infiltration of carbonate of lime, which, in many of them, has a deep tinge in the centre of the deposit, apparently derived from the presence of carbonaceous matter. Magnified 10 diam.

Fig. 3. Fragment of *Nummulina lævigata* obtained by fracture through the median plane, and showing the manner in which the marginal whorls are continued as investing layers over those previously formed, and in which the marginal septa are prolonged between these layers; showing also that each septum is composed of two layers with an intervening space. Magnified 12 diam.

Fig. 4. Fragment of *Nummulina lævigata* obtained by fracture in a direction perpendicular to the median plane; showing the chambers, *a* to *a'*, on that plane, invested by successive layers above and below; *b*, *b*, the septa between the chambers of the medial plane; *c*, *c*, passages between the inner margin of these septa and the outer margin of the preceding whorl; *d*, a chamber in the fourth whorl from the margin, invested by four layers; *e*, a chamber in the tenth whorl from the margin, invested by ten layers; *f*, *f*, investing layers; *g*, *g*, spaces between these; *h*, *h*, intervening septa prolonged from the marginal septa. Magnified 20 diam.

Fig. 5. Supposed animal of *Nummulina*, after MM. Joly and Leymerie.

Fig. 6. Fragment of *Nummulina lævigata*, obtained by fracture through the central plane, showing the doubleness of the septa through their whole course, and the separation of the two layers at *a*, *a*, to surround the perforations; showing also the minute canals in the walls of the chambers, and the openings of these canals into their cavities; and exhibiting the continuity of the marginal septa with those which divide and support the investing layers. Magnified 24 diam.

Fig. 7. Fragment of *Nummulina lævigata*, broken so as to display a marginal septum and its perforations; *a*, septum, marked with minute orifices; *b*, situation of principal passage, formed by the confluence of minuter apertures; *c*, the outer margin of the invested whorl. Magnified 45 diam.

Fig. 8. Fragment of *Nummulina lævigata*, fractured through the median plane and at right angles with it, showing the perforations, *a*, *a*, &c., passing continuously from the surface to the septa; these passages being filled up, in this specimen, by an infiltration of crystalline carbonate of lime. Magnified 24 diam.

Fig. 9. Transparent section of *Orbitoides* (from the same specimen as figs. 13 and 14) through the investing layers, in a direction parallel to the median plane; showing the vertical perforations, *a*, *a*, filled up with opake infiltration, and divided by delicate septa into smaller apertures. Magnified 60 diam.

Fig. 10. Transparent section of *Orbitoides* (species undescribed) through the investing layers, in a direction parallel to the median plane, but near the external surface, showing the large apertures, *a*, *a*, of the perforations, filled up with opake infiltration. Magnified 60 diam.

Fig. 11. Transparent section of *Nummulina obtusa* through the investing layers, in a direction parallel to the median plane, showing the perforations, *a*, *a*, filled up with opake infiltration. Magnified 60 diam.

Fig. 12. Transparent section of *Nummulina complanata*, in the same direction, showing the perforations elongated into slits, *a*, *a*, divided by transverse septa; and the metamorphosis of the tubular shell into an apparently prismatic structure, *b*, *b*. Magnified 90 diam.

Fig. 13. Transparent section of *Orbitoides* (species undescribed), taken in a direction vertical to the median plane; showing, *a*, the chambered layer occupying that plane; *b*, *b*, thick investing layers, the prolongations of which extend beyond the central layer and inclose its margin, as seen at *c*, and the vertical perforations, *d*, *d*, filled with opake infiltration. Magnified 16 diam.

Fig. 14. Transparent section from the same specimen, taken through the median plane; showing, *a*, *a*, the median chambered layer, and *b*, *b*, the investing layers (a portion of which, more highly magnified, is shown in fig. 9). Magnified 40 diam.

Fig. 15. Transparent section of a portion of *Nummulina lævigata* in a direction perpendicular to the median plane (as in fig. 4); showing, *a*, *a*, the shelly layers cut through vertically, exhibiting their minutely tubular structure; *b*, *b*, modification of that structure at the margins of the whorls; *c*, *c*, the marginal chambers; *d*, *d*, the perforations infiltrated with transparent crystalline deposit. Magnified 60 diam.

Fig. 16. Transparent section of *Nummulina lævigata*, in a direction parallel to the median plane, to exhibit the structure of the shell inclosing the mar-

ginal chambers; *a, a, a, a*, shell-wall of portions of the four chambers separated by the septa *b, b, b*, perforated by minute orifices, which are those of the parallel vertical tubuli shown in fig. 15, and traversed irregularly by canals, *c, c*, which open into the chambers by distinct orifices, *d, d*, and terminate in the intraseptal spaces. Magnified 60 diam.

Fig. 17. Transparent section of *Nummulina complanata*, in a direction vertical to the median plane, showing the several investing layers in close apposition with each other, and not separated by prolongations of the marginal chambers. Magnified 6 diam.

Fig. 18. Transparent section of *Orbitoides* (undescribed species), in a direction vertical to the median plane, presenting, in the size of its chambered layer, a close resemblance to the Nummulitic structure. Magnified 20 diam.

Fig. 19. Vertical section of *Orbitoides* (undescribed species from Scinde), with a very thin chambered layer, *a, a*, and the vertical channels (filled with opake infiltration) of unusual size. Magnified 9 diam.

Fig. 20. Vertical section of *Orbitoides Mantelli*, showing the chambered layer, *a, a*, occupying the median plane, and the investing layers, *b, b*, above and below. Magnified 60 diam.

Fig. 21. Section of *Orbitoides Mantelli* through the median plane, showing the form of the cells of the chambered layer, partly filled by calcareous infiltration. Magnified 60 diam.

Fig. 22. Section of *Orbitoides* (undescribed species from Biaritz) in a direction vertical to the median plane. Magnified 30 diam.

Fig. 23. Section of *Orbitolites complanata* through the median plane. Magnified 60 diam.

Fig. 24. Section of *Marginopora* (*Orbitolites*, recent Australian species, undescribed) through the median plane, but passing through the more superficial portion near the margin, at *a, a, a*. Magnified 10 diam.

Fig. 25. Portion of the same, taken near *a, a*, and showing the form of the cells near the surface. Magnified 60 diam.

Fig. 26. Portion of the same, taken near the centre, and showing the form of the cells nearer the median plane. Magnified 60 diam.

Fig. 27. Vertical section of the same, showing the single layer, *a, a*, of superficial chambers on each surface, and the structure of the intervening portion, *b, b*, of the disk. Magnified 60 diam.

Fig. 28. Thin slice from the edge of the disk, showing the pores opening on its margin. Magnified 90 diam.

Fig. 29. Portion of the surface of the same, viewed as an opake object, showing the superficial chambers, some of them closed in, others laid open by the abrasion of their covering. Magnified 60 diam.

Fig. 30. Portion of the surface of *Orbitolites complanata*, viewed as an opake object, showing the superficial chambers, closed in at the lower part of the figure, laid open by abrasion at the upper part. Magnified 60 diam.

Fig. 31. Portion of the surface of the chambered layer of *Orbitoides Mantelli*, showing the chambers covered in and a few laid open. The investing layers have here been removed. Magnified 30 diam.

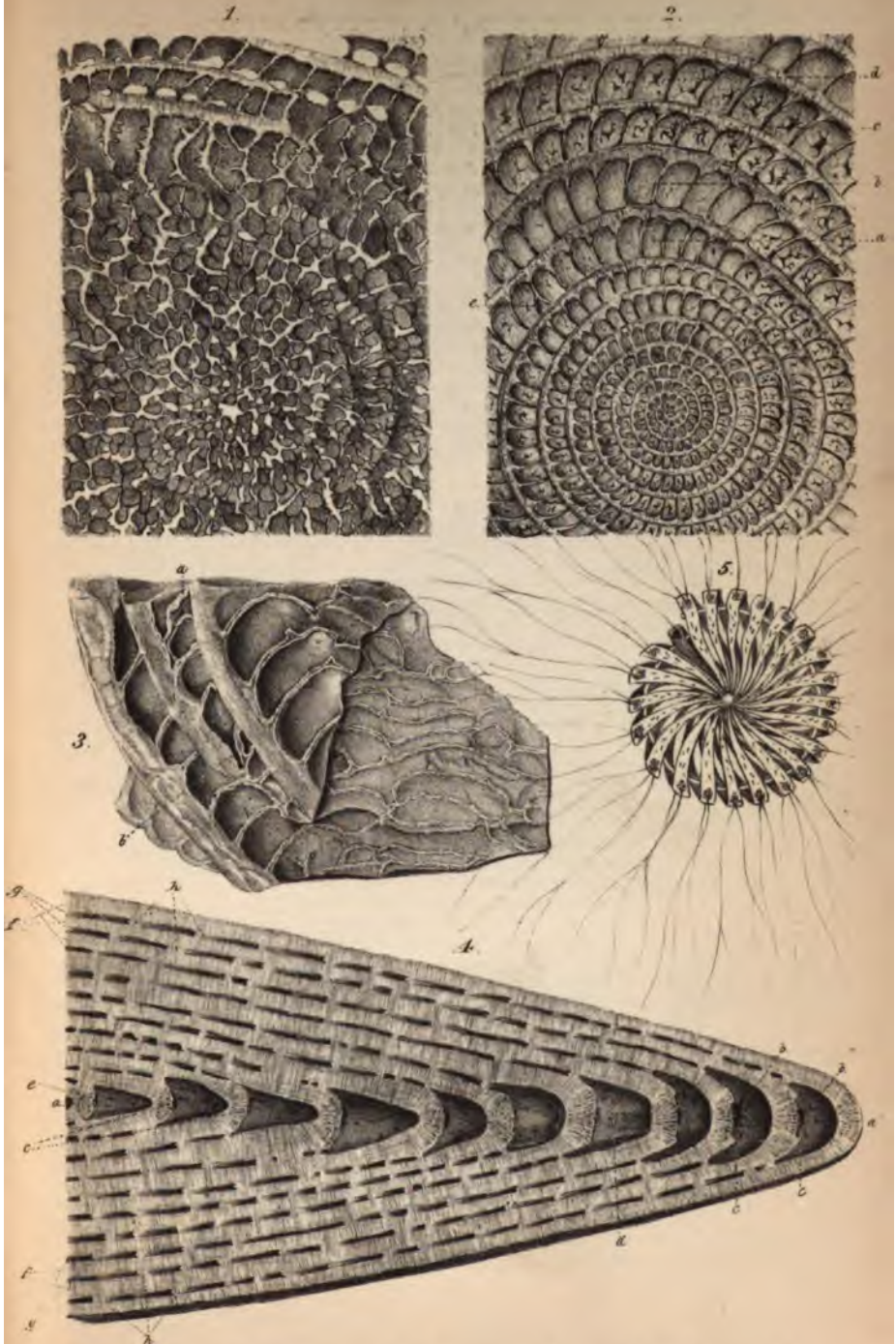
Fig. 32. Transparent section of *Orbitoides Prattii*, passing through the median plane; *a, a*, the investing layers; *b*, portions of the median chambered layer, showing at *b'* a very irregular arrangement of the chambers. Magnified 12 diam.

Fig. 33. Portion of fig. 32, *a*, more highly magnified, showing the form of the cells of the investing layers, and the perforation of the shelly substance by minute tubuli. Magnified 60 diam.

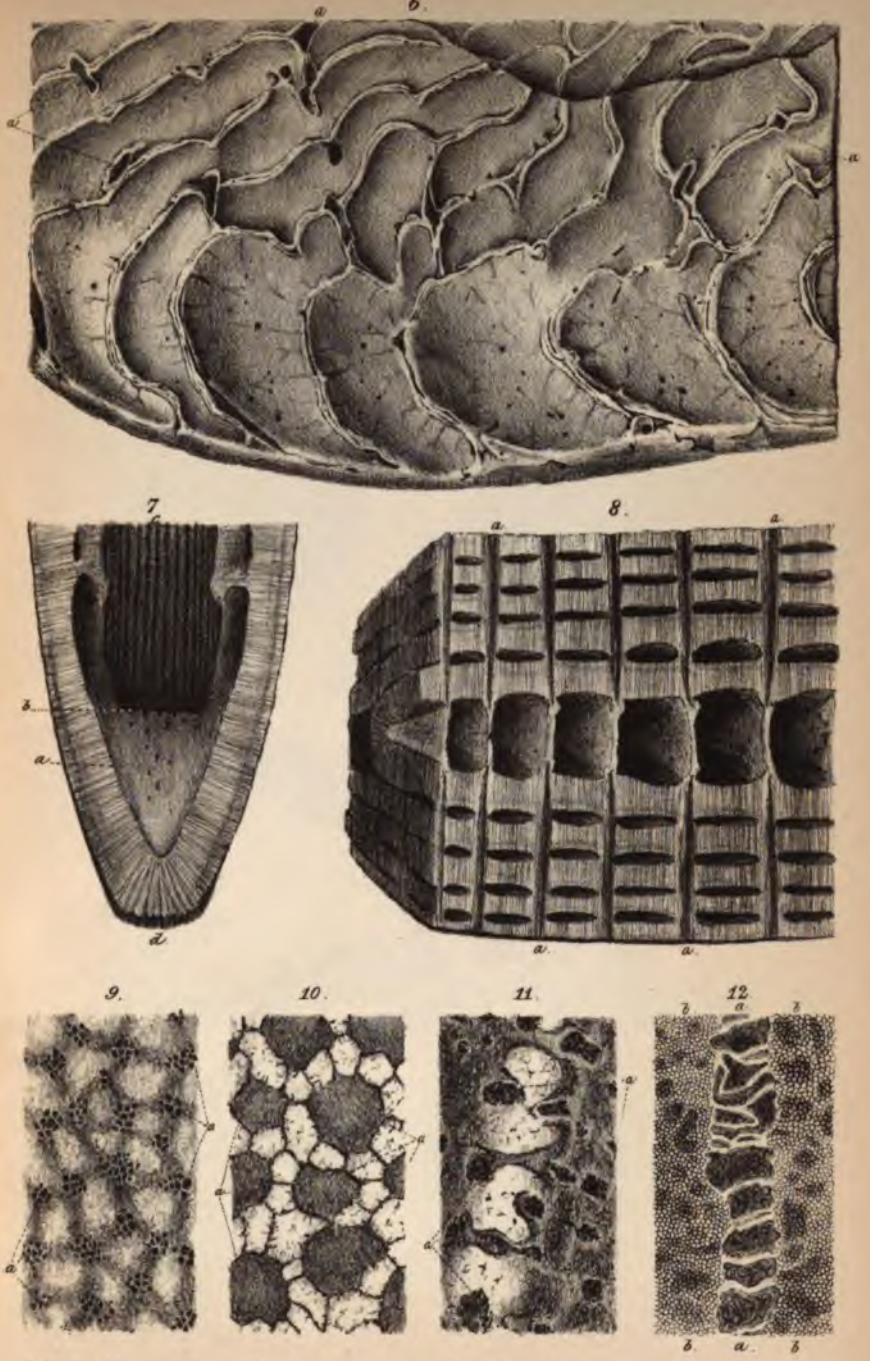
Fig. 34. Portion of fig. 32, *b*, more highly magnified, showing the form of the cells of the chambered layer. Magnified 60 diam.

Fig. 35. Vertical section of the entire disk of *Orbitoides Prattii*, showing the median chambered layer, and the investing layers above and below; at *a* is seen the large globular cell in which the chambers of Foraminifera always seem to commence. Magnified 10 diam.

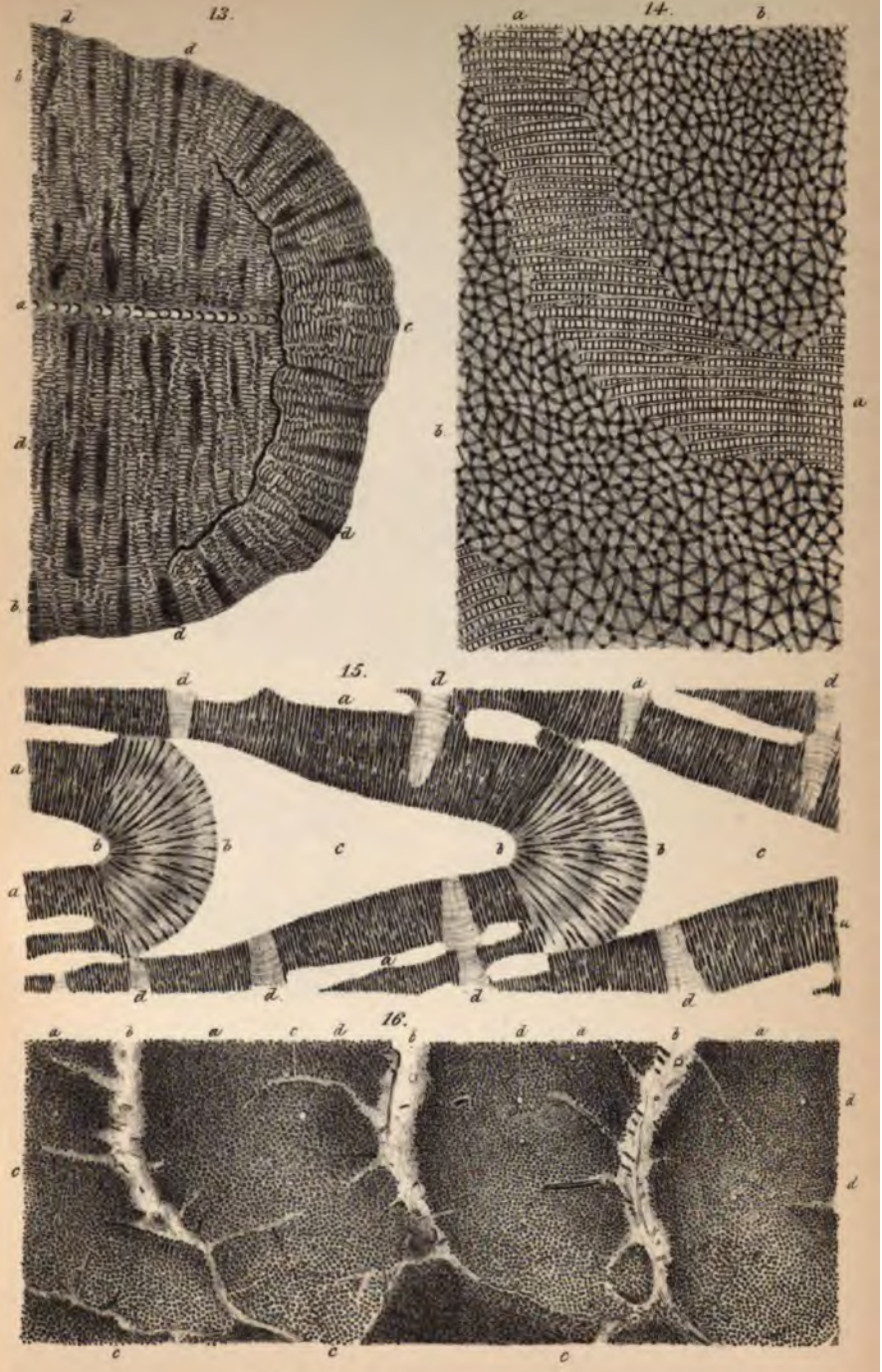
Fig. 36. Portion of the same section more enlarged, showing the chambered layer,



1.2.3.4. Nummulina lævigata; 5, supposed animal of Nummulina.



6.7.8. Nummulina lævigata. 9. Orbitoides *(undescribed species)*
10. Orbitoides *(undescribed species)* 11. Nummulina obtusa.
12. Nummulina complanata.



13. 14. Orbitoides *(undescribed species)*
15. 16. Nummulina lævigata.

17.

18.

19.

20.

22.

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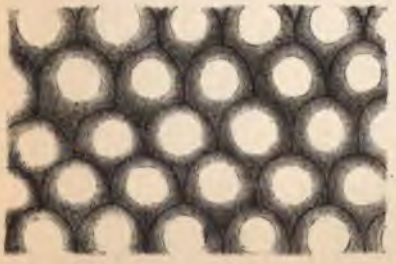
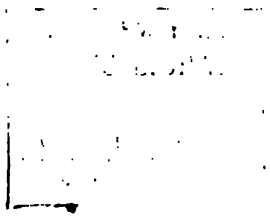
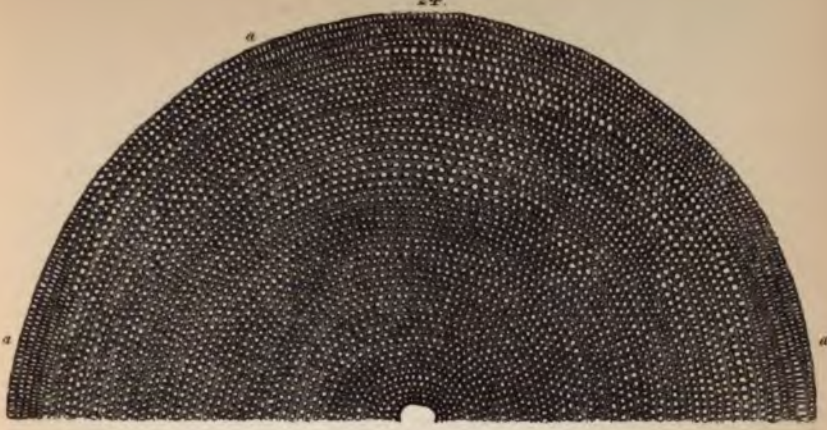
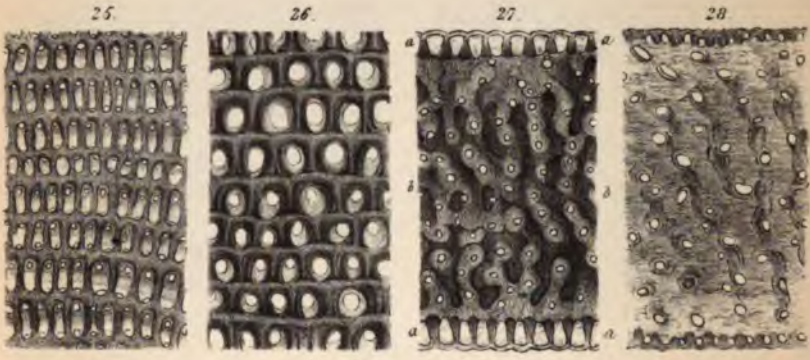


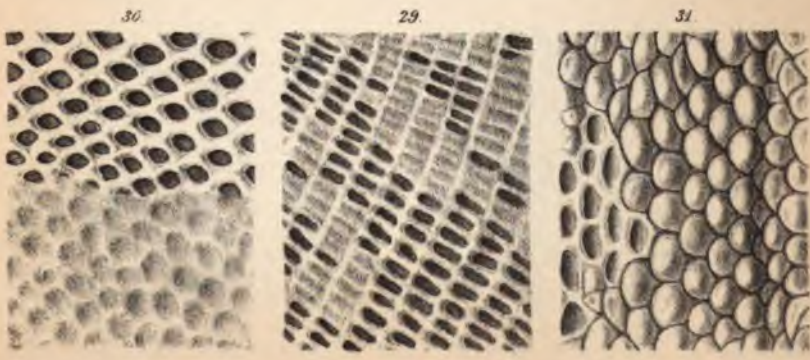
23.

17. Nummulina complanata,
18. Orbitoides *(undescribed species)*
19. Orbitoides *(undescribed species)*
20.21. Orbitoides Mantelli
22. Orbitoides *(undescribed species)*
23. Orbitolites complanata.









24-29. Marginopora (Orbitolites), recent Australian species (undescribed).
30. *Orbitolites complanata*; 31. Orbitoides Mantelli.

32.

33.

34.

35.

37.

36.

32, 33, 34, 35. 36, 37, Orbitoides Prattii

a, *a*, in the median plane, and the investing layers, *b*, *b*, above and below. Magnified 90 diam.

Fig. 37. Portion of the surface of *Orbitolites Prattii*, viewed as an opake object, showing the absence of any definite indications of cells or chambers. Magnified 30 diam.

May 16, 1849.

C. Bagot Lane, Esq., C.E., was elected a Fellow of the Society.

The following communications were read:—

1. *On some Tertiary Beds in the* Island of San Domingo: *from Notes by* J. S. Heniker, Esq., *with Remarks on the Fossils, by* J. Carrick Moore, Esq., Sec.G.S.

In the north-eastern part of the island of San Domingo, at an average distance of about 30 miles from the sea, runs a range of mountains with an east and west direction, consisting of mica schist. Between this range and the northern sea an extensive tertiary formation occurs, being about 30 miles broad, and at least 100 miles in length from east to west. It is intersected by several rivers, the principal of which is the Yaqui, on which stands the town of San Jago, distant from the sea about 20 miles, and elevated more than 2000 feet above it. The rivers have cut narrow channels through the strata, which are thus exposed in perpendicular cliffs often 200 feet high. These cliffs near the bottom consist of a bluish sandy shale, whence Mr. Heniker extracted the greater part of the fossils shortly to be mentioned. Higher up the beds become more argillaceous, and contain but few shells, with some corals. This formation is overlaid conformably by tufaceous limestone, which has suffered much denudation, and forms a low range of arid hills, about 500 feet high, resembling chalk downs in their rounded outline, and scantily covered by a dwarfish vegetation. At the foot of these hills, in loose sand covering the shelly deposits, Mr. Heniker found fishes' teeth. These formations dip gently to the N.N.W., and intermediate between them and the sea a red sandstone is found, dipping also to the N.N.W., but at a much more considerable angle. Mr. Heniker has not been able to ascertain its relation to the limestone and shale, but he suspects it to be older. No organic remains are found in it. From the shales and the sand which caps them Mr. Heniker procured the following fossils:—fishes' teeth, a crab, 84 species of mollusca, an echinoderm, 18 species of coral, numerous foraminifera, dicotyledonous wood.

Sir Philip Egerton, who obligingly examined the fishes' teeth for me, states that they belong to the *Carcharodon megalodon*, Agassiz, found in the crag, the Malta beds, the miocene formations of America, &c.

The Corals have been laid before Mr. Lonsdale, who has not had time to examine them in detail: he however informs me that they belong to 18 species; some of them, apparently taken from a super-

ficial or vegetable soil, have a more recent aspect than others which are found in a light-coloured sand: none of them were referable to the fossil corals of America known to Mr. Lonsdale.

The Echinoderm is a scutella closely allied to, if not identical with, a recent species.

Mr. Morris, who kindly examined the Foraminifera, informs me that four are identical with the following known species:—

Nodosaria raphanistrum ...	Fossil at Malta, &c.
—— affinis	Fossil at Vienna.
Robulina cultrata	Recent, and fossil at Vienna, Sienna, &c.
Rosalina Beccarii	Recent, and fossil at Bordeaux.

Others belong to the genera *Textularia*, *Dentalina*, &c.

The Mollusca were compared by Mr. G. B. Sowerby and myself with such recent and tertiary shells as we could get access to, more especially with the rich collection of American tertiary shells in the possession of Sir Charles Lyell, who most kindly permitted us to consult his museum. The result was as follows. Omitting such as are too imperfect for specific determination, the shells are referable to 77 species, belonging to the following genera:—

	No. of Species.		No. of Species.
Conus	9	Turbinellus	3
Oliva	2	Pleurotoma	6
Cypræa	1	Cerithium	2
Marginella	1	Solarium	1
Voluta	2	Petaloconchus	1
Mitra	2	Natica	2
Columbella	3	Bulla	3
Terebra	3		—60
Nassa	1	Venus	1
Phos	1	Tellina	1
Cassis	1	Lucina	2
Cassidaria	1	Cardium	1
Oniscia	1	Chama	1
Strombus	4	Arca	2
Triton	2	Pecten	3
Typhis	1	Pectunculus	2
Murex	1	Ostræa	3
Pyrula	1	Spondylus	1
Fusus	2		—17
Fasciolaria	2		—
Cancellaria	1		77

Of these Mr. G. B. Sowerby considers 13 to be identical with existing species; while with respect to two more he entertains some doubt. The following is the list:—

Oliva hispidula, *Lam.* (var.)...	Hab.	West Indies.
Columbella mercatoria	„	West Indies.
Nassa incrassata (var.)	„	Brit. and Mediterr.
Phos Veraguensis, and var. ...	„	Coast of Veragua, Pacific.
5. Triton femoralis.....	„	West Indies.
Turbinellus ovoideus	„	West Indies.
Cancellaria reticulata (var.) ...	„	West Indies.
Natica sulcata.....	„	West Indies.
Bulla striata, *Lam.*	„	West Indies.
10. Venus puerpera, *Linn.*	„	Indian seas.

Lucina pensylvanica, *Lam.* ...	Hab.	West Indies.
—— tigerrina	„	West Indies.
13. Chama arcinella	„	West Indies.
Tellina ephippium?	„	Indian seas.
Ostræa Virginica?	„	Coasts of America.

Of these 13 recent shells, 5 have been found fossil in the following localities :—

Nassa incrassata	Bordeaux, Dax, Cor. Crag, Sub-Apennines, Sicily.
Bulla striata, *Lam.*	Montpellier, Perpignan.
Chama arcinella	Miocene beds of United States.
Lucina pensylvanica, *Lam.* ...	Miocene of Piedmont.
—— tigerrina	Bordeaux, Sub-Apennines, &c.

The large *Ostræa Virginica* is also found fossil at Bordeaux, and in American miocene beds.

Of the remainder, two are closely allied to *Pleurotoma oblonga*, of the Bordeaux and Touraine beds, and *P. vulpecula*, of the Sub-Apennines. An Oniscia and a Turbinellus are not to be distinguished, by the engravings or descriptions, from *O. harpula* and *T. Wilsoni* of Conrad, in the upper eocene of the Mississippi; and an Ostræa is identical with *O. callifera* of the Paris basin and the Brussels beds.

Mr. Sowerby has favoured me with descriptions of 59, which he considers new; these are appended to this notice, and in fact form the more important part of it. Shells of the following genera also occur, but not sufficiently preserved for specific determination :— *Murex, Turritella, Turbo, Pasithea, Rissoa, Dentalium, Cytherœa, Cardium, Pinna, Lithodomus.*

Of the new species there is one which calls for a remark. Mr. Lea* has formed a new genus, *Petaloconchus*, for a shell, found in the miocene beds of Petersburgh, Virginia, which resembles a Vermetus in general characters, but differs from it in having two internal raised plaits or bands running spirally along the columella, like those of a Volute. In the young state of the shell these bands either do not exist or are very faint, and they also seldom continue to the mouth. Finding a shell with these characters among the San Domingo fossils, I was curious to learn whether any known shells described as Vermeti might not also possess them, although, for want of a fracture in the more central parts, it had not been observed. I accordingly examined all the vermetiform shells I could find, and satisfied myself that the following three well-known shells also have this character, and are therefore true Petaloconchi :—

Vermetus subcancellatus ...	Fossil in	Touraine, Bordeaux.
—— intortus	„	Bordeaux? Piacenza, Crag.
—— glomeratus (Brocchi)...	„	Bordeaux, Sienna, Zante.

I have not found one species among recent Vermeti†, nor in for-

* Trans. Amer. Phil. Soc. vol. ix. p. 229.

† *Vermetus subcancellatus* and *V. glomeratus* are enumerated by Dr. Philippi as recent and fossil in Sicily. Through the kindness of Mr. Hanley I have seen specimens of each of the recent shells, which he had received from Dr. Philippi:

mations older than those of Touraine or Bordeaux. Thus, of the four described species, including Mr. Lea's *Petaloconchus sculpturatus*, three are confined to miocene beds, and the fourth occurs in both miocene and older pliocene formations. Some probability hence arises that the San Domingo beds which contain this fifth species are also to be referred to the middle tertiary epoch.

In speculating upon the age of these deposits, the first question is, whether all their organic contents belong to the same formation. Upon this point the evidence of Mr. Heniker, though not a practised field-geologist, deserves great weight. He informs us, that though the fossils were collected from five different localities, by far the greater number were procured by himself from one spot, and the remainder from beds apparently in the same stratigraphical position; so that he entertains little doubt on this head. As some corroboration of this view, I may state, that the matrix in which the fossils were imbedded appeared to me of only two kinds, and different specimens of the same fossil were frequently incrusted with each.

Assuming therefore this to be true, we have a deposit containing 77 species of Mollusca, of which 13 are unquestionably recent, and 2 doubtful. Excluding the doubtful, the proportion of 13 to 75 is exactly $17\frac{1}{3}$ per cent.; and should the 2 doubtful hereafter be identified with recent shells, the proportion of 15 to 77 is $19\frac{1}{2}$ per cent.

It is obvious that this formation is of quite a different order from the fossil beds in Barbadoes and Antigua, every species in which is now found living in the adjoining seas. Neither have I been able to identify one shell with those from the older tertiary rock in Barbadoes, described by Sir R. Schomburgk, or those from Jamaica in the Society's collection. If we take as our guide the law of the proportion of recent to extinct forms, the ratio of 17 or 20 per cent. would refer this formation to the miocene period of Europe: and the facts that all the Foraminifera and Mollusca which have been identified with known fossil forms occur in beds of that high antiquity, and perhaps in one or two cases older,—the presence of a genus of shell of which no species has been found in beds older than the American miocene or newer than the Sub-Apennines,—the occurrence of the teeth of the great Carcharodon, considered by Agassiz as very characteristic of miocene formations,—together with the general resemblance and the close analogy of some of the fossils to those of Touraine and Bordeaux,—all seem confirmatory of this view.

It may seem remarkable that there is no greater specific resemblance between these shells and those from the miocene beds of the United States. But when it is remembered that the most southern miocene deposits of America are in lat. 33°, while those of San Domingo are in lat. 19°, a difference equal to that between Rome and Edinburgh, this will scarcely invalidate the conclusion.

neither of them has plaits on the columella; and as it is impossible to doubt the accuracy of that gentleman's identification of the recent shells with the Sicilian fossils, I cannot but suspect that these Sicilian shells are distinct from their two synonyms in the Touraine, Bordeaux, and Piacenza beds.

Mr. Conrad* has lately described a formation in South Carolina, in the bluffs of the Mississippi, which is distinctly newer than the eocene beds of Claiborne. Out of 177 shells, it contains only two which are common to it and the subjacent eocene, while not a single species is identical with existing forms. In the upper part of it are found the teeth of the *Carcharodon megalodon*. To this formation Mr. Conrad has provisionally given the name of upper eocene. Two of the shells are undistinguishable, by their engravings and descriptions, from two of the San Domingo shells, and a great many are closely allied. Should it prove on further examination that the San Domingo beds are referable to two formations, the recent species being principally confined to the upper and the extinct to the lower, I think it probable that the lower would be found nearly related to those so-called upper eocene beds in South Carolina.

There is a character attached to a portion of this collection which is too remarkable to leave unnoticed. Mr. Sowerby was much struck with the resemblance of many of the shells to recent species inhabiting the seas of China, Australia, and even the western coast of America; a resemblance so close, that that naturalist hesitated before pronouncing them to be distinct; whilst he identifies without any doubt two of the shells with the recent *Venus puerpera* (Linn.) of the Indian Ocean, and the *Phos Veraguensis* which was dredged up in the Bay of Veragua by Mr. Hinds, during the Voyage of the Sulphur. It is certainly remarkable to find a shell living in the same latitude with its fossil analogue, and separated from it only by a narrow isthmus, when it is recollected upon what grounds the high antiquity of the division of the Atlantic and Pacific Oceans into distinct faunas has been established. M. D'Orbigny has shown that the tertiary beds which flank the two sides of the Cordilleras do not contain one species in common. Mr. Conrad has lately published a list of all the recent shells known to him which are found in the American miocene, 49 in number, which without an exception are Atlantic species. Sir C. Lyell has shown that most of the recent shells found in the miocene of the United States are confined to the western shores of the Atlantic. To this there is one exception, the *Calyptræa costata*, which is found living at Valparaiso and fossil in American miocene beds. It must be remembered that M. D'Orbigny's conclusions are formed from shells derived from latitudes 31° to 40° S.; and the most southern of the North American miocene beds are in lat. 33° N.: so that a channel or sound may have existed in the equatorial parts during some portion of the tertiary period, by which some few of the tropical shells may have migrated from the one ocean to the other, while those living 30° to the north or south of the line would be as effectually separated as those actually living in the two oceans 30° north of the Straits of Magellan. It should be borne in mind that the Isthmus of Panama is not merely narrow, but low land: the continuity of the Andes (I quote Mr. Hinds' words) is here quite broken; and instead of the table land north of Nicaragua of the height of 4500

* American Journal of Science, 1846, New Series, i.

feet, or the peaks of the Andes to the south reaching to 11,000 feet, the Isthmus nowhere attains 1000, that is, one-half the height through which these beds of San Domingo have been elevated since their deposition.

It is to be hoped that Mr. Heniker, to whom we are indebted for this interesting collection, will continue his researches, and clear up the doubt which I have ventured to suggest, whether these fossils belong to the same or to two formations of different geological age.

Descriptions of new Species of Fossil Shells found by J. S. Heniker, Esq. By Mr. George B. Sowerby.

Conus Haytensis.

Testa oblongo-turbinata, conica, lævis, crassiuscula, spirâ subproductâ, spiraliter striatâ, anfractibus primis subcoronatis, ultimi margine postico rotundato anguloso, ad basin striato; aperturâ amplâ, postice rotundato-emarginatâ; canali subreflexo.

A variable species; at the same time it cannot be confounded with any known species.

Conus symmetricus. Pl. IX. fig. 1.

Testa turbinata, crassiuscula, breviuscula, granulosa, spirâ brevi, spiraliter striatâ, anfractuum marginibus angulatis; ultimo anfractu zonis angustis, pluribus, elevatis, granosis, lateribus æqualibus, canali subproducto, leviter reflexo.

A beautiful small Cone, having the last volution covered with granular zones.

Conus stenostoma.

Testa turbinata, regularis, crassa, lævigata, spirâ mediocri, subacuminatâ, lineis incrementi obsoletis solum conspicuis; anfractibus primis leviter subcoronatis, ultimo postice angulato, mediane et antice transversim lirato, liris subdistantibus, subprominulis; aperturâ angustâ, labii externi sinu postico magno.

Remarkable for the narrowness of its mouth and the great size of the posterior sinus of the outer lip, as evidenced by the lines of growth on the spire.

Conus planiliratus.

Testa turbinata, crassa, transversim sulcata, spirâ breviter acuminatâ, lævi, substriatâ; anfractu ultimo liris elevatis, numerosis, confertis, superne planis cincto; interstitiis longitudinaliter tenerrime striatis.

About twenty prominent, flat-topped ridges may be counted on the last volution.

Conus marginatus.

Testa subturbinata, utrinque subæqualis, sulcata, spirâ conicâ, subacuminatâ, anfractuum marginibus prominulis; anfractu ultimo transversim costellato, costellis 16 acutangulis.

Deeply grooved externally, and having the edge of the volutions composing the spire rather prominent.

Conus Domingensis.

Testa turbinata, subpyriformis, crassiuscula, lævis, spirâ elevatâ, spiraliter striatâ, anfractibus primis subcoronatis, marginibus subelevatis, ultimo anfractu postice subventricoso, antice striato, striis granosis, moniliformibus.

This is a somewhat variable species, particularly in the elevation of the spire.

Conus solidus.

Testa turbinata, conica, crassa, lævis, spirâ subproductâ, lævi, anfractuum marginibus rotundato-elevatis; anfractu ultimo striato, striis paucis, subobsoletis, canali recto.

This fossil is remarkable for retaining some traces of its living colours, the spire is marked with light rusty-brown dashes, and there are three rows of spots of the same colour on the last volution.

Conus catenatus. Pl. IX. fig. 2.

Testa oblongo-turbinata, spirâ productâ, mucronatâ, anfractibus canaliculatis, ultimo anfractu lævi, antice obsolete sulcato, liris nonnullis granosis, sulcis alternantibus, granis paucis, parvis, distantibus.

Conus consobrinus.

Testa oblongo-turbinata, crassiuscula, granulosa, spirâ conicâ, elevatâ, coronatâ, spiraliter striatâ, ultimo anfractu zonis elevatis, angustis plurimis granosis, canali subproducto.

Also a variable species; in one specimen the granose zones only cover half the shell. It bears some resemblance to *Conus cedo-nulli*.

Oliva cylindrica.

Testa subcylindrica, spirâ brevi, retusâ, labii columellaris dentibus validis, obtusiusculis, calli umbilicali dentibus sex ad septem elongatis, quorum altero brevi.

Cypræa Henikeri. Pl. IX. fig. 3.

Testa obovata, ventricosa, inflata, lævis, dorso postice irregulariter tuberculifero, lateribus, præcipue sinistro, obsolete granosis; extremitatibus, posticâ brevissimâ, anticâ subproductâ, aperturâ angustâ, marginibus dentatis, dentibus paucis, magnis, rotundatis, canali brevissimo, reflexo.

This species bears a general resemblance to *Cypræa Mus* and several others, which occasionally have irregular tubercles on the posterior part of the back; it may however be easily distinguished from all such by the dentition of both edges of the aperture, the teeth in this species, though not numerous, being large and prominent.

Marginella coniformis.

Testa oblongo-ovata, antice acuminatior, spirâ brevissimâ, submucronatâ, aperturâ rectiusculâ, angustâ, labii externi margine inflexo, lato, crasso, depresso, ad apicem continuo, margine interno crenulato: labio columellari antice incrassato, supra anfractum ultimum extenso, plicis quatuor, prominulis, distantibus, duabus anticis elongatis, obliquis, parallelis, anticâ latus alterum canalis formante, antepenultimâ minus parallelâ, posticâ transversâ.

This species comes nearest to *Marginella Amygdala* of Kiener; it

differs from that species, however, in having a straight narrow aperture, a flat wide outer lip, its inner edge being crenulated, its large, coarse and distant columellar plaits, and in its general shape.

Voluta pulchella. Pl. IX. fig. 4.

Testa oblongo-ovata, lævis, longitudinaliter costata, anfractibus senis subrotundatis, spirâ acuminatâ; costellis plerumque antice subobsoletis; labio externo intus lævi, columellâ plicatâ, plicis anticis majoribus.

There are apparently two varieties of this species, one of which is smaller and rather wider; its ribs are also rather fewer, and more generally somewhat obsolete anteriorly.

Voluta soror.

Testa ovato-oblonga, lævigata, anfractu ultimo oblique longitudinaliter costato, antice transversim striato; margine interno labii externi denticulato, plicis labii columellaris distantibus, posticis parvis.

There is only a single individual of this species, which has lost its spire; it is distinguishable from *V. pulchella* by its greater size, and by the obliquity of the longitudinal ribs.

Mitra Henikeri. Pl. IX. fig. 5.

Testa oblongo-fusiformis, utrinque acuminata, anfractibus septem, spiraliter sulcatis, sulcis majoribus minoribusque alternantibus, ad basin decussatis; margine labii externi crenulato; plicis columellaribus duabus posticis validis, anticâ solitariâ obsoletâ.

This species is nearest in form to the recent *M. filosa*, which has four plicæ on the columella.

Mitra varicosa.

Testa oblongo-subfusiformis, anfractibus subventricosis, liris majoribus minoribusque asperis alternantibus, varice asperâ prope suturam distinctâ; plicis columellaribus posticis duabus, validis, tertiâ obsoletâ.

Remarkable for its two prominent columellar plicæ, and for the spiral varix placed at the posterior part of the volutions near the suture. A fragment only exists.

Columbella Haitensis.

Testa ovalis, anfractibus senis, spiraliter striatis, transversimque costellatis, anfractu ultimo ventricoso; aperturâ latiusculâ, canali brevi, reflexâ, extus striatâ; suturâ validâ; columellâ postice rugulosâ; labio externo intus dentibus quatuor ad quinque induto.

A very small species, not quite three-eighths of an inch in length, and nearly one-eighth in width.

Columbella venusta. Pl. IX. fig. 6.

Testa oblongo-acuminata, crassa, anfractibus 9, subventricosis, longitudinaliter costellatis, costellis flexuosis, transversim sulcatis, sulcis crebris, costellas decus-

santibus; suturâ validâ; margine interno labii externi dentibus elongatis 7 ad 8 labio columellari intus ruguloso; canali brevi, leviter reflexâ.

This very elegant Columbella differs entirely from any other known species.

TEREBRA SULCIFERA.

Testa aculeiformis, anfractibus plurimis, oblique transversim sulcatis, prope suturam incrassatis, sulcis spiralibus duobus prope suturam admotis, tertio antico subobsoleto ad basin anfractûs remoto.

TEREBRA INÆQUALIS.

Testa turrito-subulata, subcylindracea, anfractibus planulatis, longitrorsum plicato-costellatis, postice lineâ impressâ cinctis, costellis posticis obliquis, anticis arcuatis; anfractu ultimo antice subangulato; columellâ antice biplicatâ.

The deep impressed spiral line divides the volutions into unequal parts.

TEREBRA BIPARTITA.

Testa turrito-subulata, acuminata, anfractibus planulatis, longitrorsum plicato-costellatis, postice lineâ impressâ costellis decussatâ cinctis, costellis posticis subevanidis, anticis subarcuatis; anfractu ultimo antice rotundato, columellâ antice lævi.

This species somewhat resembles *T. duplicata*, particularly in its general shape.

CASSIS SULCIFERA. PL. X. fig. 1.

Testa ovato-trigona, crassiuscula, anfractibus senis, longitudinaliter sulcatis, ultimo seriebus duabus ad tribus tuberculorum ornato, serie posticâ eminentiore; aperturâ latâ; margine interno labii externi dentato, dentibus paucis distantibus; labio interno transverse costellifero; costellis anticis prominentioribus.

CASSIDARIA LÆVIGATA. PL. X. fig. 2.

Testa ovata, utrinque subacuminata, plerumque lævis, nonnunquam transversim striata, anfractibus senis, varicibus tenuibus nonnullis ornatis; aperturâ oblongâ, postice acuminatâ, margine interno labii externi dentato, dentibus elongatis pliciformibus; labio columellari antice posticeque ruguloso.
Variat testâ majori, ventricosiori.

ONISCIA DOMINGENSIS. PL. X. fig. 3.

Testa ovato-oblonga, subventricosa, crassiuscula, anfractibus senis, coronatis, decussatim costatis, postice subplanulatis; aperturâ elongatâ, postice acuminatâ, margine interno labii externi transversim costellifero, costellis sub-bifariam coordinatis; labio columellari granuloso.

When young the granules of the columellar lip are indistinct, and do not extend so as to cover the lip, but when full-grown the columellar lip is entirely covered with granules; in which character it differs from *O. cancellata*. It is also distinguished from that species by the nature of the denticulations on the inside of the outer lip, which in *O. Domingensis* are extended across the lip. It is worthy of remark, that *O. cancellata* is a Chinese species.

STROMBUS AMBIGUUS.

Testa ovato-elongata, postice acuminata, transversim dense striata, anfractibus octo, primis transversim costellatis, anticis duobus tuberculiferis, tuberculis parvis, rotundatis; aperturâ latiusculâ, labio exte... ...rno extus varice distinctâ, intus ruguloso, labio columellari intus postice ruguloso.

Distinguished from *Str. bifrons* by the rugulosities at the posterior inner part of the columellar lip, as well as by the form of the tubercles.

STROMBUS HAITENSIS. PL. IX. fig. 7.

Testa suboblongo-turbinata, transversim sulcata, spirâ pyramidali, acuminatâ, subundulatâ, varicosâ, anfractibus novem, ultimo ad dorsum tuberculato, tuberculorum seriebus duabus, alterâ posticâ, tuberculis subdepresso-acuminatis; alterâ anticâ, tuberculis duobus vel tribus sistente; tuberculo parvo prope labium remoto; aperturâ elongatâ, labii externi crassi margine inflexo.

A species which closely resembles *Str. inermis* of Swainson, from which it may be distinguished by its peculiarly-arranged tubercles.

STROMBUS PROXIMUS. PL. IX. fig. 8.

Testa ovato-oblonga, antice posticeque acuminata, transverse striata, anfractibus novem, posticis transversim costellatis, varicosis, anticis duabus tuberculiferis, tuberculis acuminatis, ultimo nonnunquam seriebus tuberculorum duabus; aperturâ latiusculâ, subexpansâ, intus lævissimâ, canali subreflexo.

This differs from *Str. gracilior*, Sow. (to which species it is most nearly allied), in having the inner part of both lips quite smooth, the outer surface of the two last volutions distinctly striated, and in the first volutions being transversely ribbed and not tuberculated.

STROMBUS BIFRONS. PL. IX. fig. 9.

Testa ovato-oblonga, utrinque acuminata, transversim striata, anfractibus octo, primis transversim costellatis, anticis duobus postice tuberculatis, serie tuberculorum unicâ, tuberculis acuminatis; aperturâ latiusculâ; labio externo extus varice unicâ subdistinctâ intus ruguloso, labio columellari lævissimo.

This species bears some resemblance to *Str. Columba*, but is very easily distinguished.

TRITON SIMILLIMUS.

Testa ovato-elongata, postice acuminata, distorta, varicibus quatuor ad quinque indistinctis, anfractibus octo, liris elevatis clathratis, tuberculiferis ornatis; columellâ profundiuscule excavatâ, ad laterem canalis dentibus rugosâ, callositate postice armatâ; labro subplano, margine interno dentato, dentibus validis, tertio maximo; margine labri externo dentibus mediocribus, continuis; canali subreflexo; anfractûs ultimi parte posticâ internâ dentibus duobus oblongis, magnis.

Nearly related to *Tr. decipiens* of Reeve, but distinguishable by the greater coarseness of the decussating ridges and the tubercles formed at their junction.

TYPHIS ALATUS. PL. X. fig. 4.

Testa ovato-oblonga, subfusiformis, transversim striata, anfractibus senis, quadri-

fariam varicosis, costellis brevibus intermediis; varice ultimo lato, tenui, radiatim striato, canali longiusculo, obtecto.

Distinguished by the tenuity and great extent of the wing-like varix from all known species.

MUREX DOMINGENSIS. PL. X. fig. 5.

Testa subovata, utrinque subacuminata, trifariam varicosa, anfractibus senis, longitudinaliter costellatis, spiraliter valide striatis; varicibus prominentibus, rotundatis, marginibus paucispinosis, spinis brevissimis; labio columellari antice ruguloso; canali breviusculâ.

PYRULA CONSORS.

Testa obovata, ventricosa, lævis, transversim striata; anfractibus quinque, primis tuberculatis, ultimo seriebus duabus ad tribus postice, antice serie solitariâ ornatis; aperturâ oblongâ, latâ; canali lato, brevi; columellâ antice subangulatâ, planulatâ.

This species nearly resembles *P. Melongena*, Lam., which is a recent species from the West India islands: it may be distinguished by its shorter figure, by being more ventricose, by the pointed tubercles on the spire, and its shorter and wider canal.

FUSUS HENIKERI.

Testa elongato-fusiformis, gracilis, postice elongato-acuminata, anfractibus plurimis, ventricosis, longitudinaliter costiferis, spiraliter liratis, costis rotundatis, liris acutis; canali elongatâ, extus liratâ, margine interno labii columellaris ruguloso; labii externo intus sulcato.

Remarkable for being distinctly longitudinally ribbed and spirally grooved; the inside of the outer lip is also grooved, and the inner edge of the columellar lip is rugulose.

FUSUS HAITENSIS.

Testa elongato-fusiformis, gracilis, postice elongato-acuminata, anfractibus plurimis, ventricosiusculis, undique spiraliter liratis, liris prominentibus acutis, mediană duplicatâ majori, longitudinaliter costatis, liris costas decussantibus; canali validâ, liris posticis distinctis, anticis subobsoletis.

Most like *F. Toreuma*, Desh., but distinguished by the central elevated ridge being formed of two lines, and being more prominent than the remainder.

FASCIOLARIA SEMISTRIATA.

Testa oblongo-fusiformis, anfractibus senis, antice posticeque spiraliter striatis, mediane lævibus; striis duabus elevatis prope suturam conspicuis.

This species most nearly resembles *F. fusiformis* of Reeve; it may, however, be easily distinguished, by the middle part of the volutions being free from the spiral striæ.

FASCIOLARIA INTERMEDIA.

Testa oblongo-fusiformis, anfractibus senis, primo lævi papilliformi, secundo, tertio et quarto tuberculatis, cæteris ventricosis, lævibus; canali longiusculo.

A single specimen with a papillary apex, like that of *F. papillosa*, Sow. Tank. Cat.

STROMBUS AMBIGUUS.

Testa ovato-elongata, postice acuminata, transversim dense striata, anfractibus octo, primis transversim costellatis, anticis duobus tuberculiferis, tuberculis parvis, rotundatis; aperturâ latiusculâ, labio exte[illegible]no extus varice distinctâ, intus ruguloso, labio columellari intus postice ruguloso.

Distinguished from *Str. bifrons* by the rugulosities at the posterior inner part of the columellar lip, as well as by the form of the tubercles.

STROMBUS HAITENSIS. PL. IX. fig. 7.

Testa suboblongo-turbinata, transversim sulcata, spirâ pyramidali, acuminatâ, subundulatâ, varicosâ, anfractibus novem, ultimo ad dorsum tuberculato, tuberculorum seriebus duabus, alterâ posticâ, tuberculis subdepresso-acuminatis; alterâ anticâ, tuberculis duobus vel tribus sistente; tuberculo parvo prope labium remoto; aperturâ elongatâ, labii externi crassi margine inflexo.

A species which closely resembles *Str. inermis* of Swainson, from which it may be distinguished by its peculiarly-arranged tubercles.

STROMBUS PROXIMUS. PL. IX. fig. 8.

Testa ovato-oblonga, antice posticeque acuminata, transverse striata, anfractibus novem, posticis transversim costellatis, varicosis, anticis duabus tuberculiferis, tuberculis acuminatis, ultimo nonnunquam seriebus tuberculorum duabus; aperturâ latiusculâ, subexpansâ, intus lævissimâ, canali subreflexo.

This differs from *Str. gracilior*, Sow. (to which species it is most nearly allied), in having the inner part of both lips quite smooth, the outer surface of the two last volutions distinctly striated, and in the first volutions being transversely ribbed and not tuberculated.

STROMBUS BIFRONS. PL. IX. fig. 9.

Testa ovato-oblonga, utrinque acuminata, transversim striata, anfractibus octo, primis transversim costellatis, anticis duobus postice tuberculatis, serie tuberculorum unicâ, tuberculis acuminatis; aperturâ latiusculâ; labio externo extus varice unicâ subdistinctâ intus ruguloso, labio columellari lævissimo.

This species bears some resemblance to *Str. Columba*, but is very easily distinguished.

TRITON SIMILLIMUS.

Testa ovato-elongata, postice acuminata, distorta, varicibus quatuor ad quinque indistinctis, anfractibus octo, liris elevatis clathratis, tuberculiferis ornatis; columellâ profundiuscule excavatâ, ad laterem canalis dentibus rugosâ, callositate postice armatâ; labro subplano, margine interno dentato, dentibus validis, tertio maximo; margine labri externo dentibus mediocribus, continuis; canali subreflexo; anfractûs ultimi parte posticâ internâ dentibus duobus oblongis, magnis.

Nearly related to *Tr. decipiens* of Reeve, but distinguishable by the greater coarseness of the decussating ridges and the tubercles formed at their junction.

TYPHIS ALATUS. PL. X. fig. 4.

Testa ovato-oblonga, subfusiformis, transversim striata, anfractibus senis, quadri-

fariam varicosis, costellis brevibus intermediis; varice ultimo lato, tenui, radiatim striato, canali longiusculo, obtecto.

Distinguished by the tenuity and great extent of the wing-like varix from all known species.

MUREX DOMINGENSIS. PL. X. fig. 5.

Testa subovata, utrinque subacuminata, trifariam varicosa, anfractibus senis, longitudinaliter costellatis, spiraliter valide striatis; varicibus prominentibus, rotundatis, marginibus paucispinosis, spinis brevissimis; labio columellari antice rugulose; canali breviusculâ.

PYRULA CONSORS.

Testa obovata, ventricosa, lævis, transversim striata; anfractibus quinque, primis tuberculatis, ultimo seriebus duabus ad tribus postice, antice serie solitariâ ornatis; aperturâ oblongâ, latâ; canali lato, brevi; columellâ antice subangulatâ, planulatâ.

This species nearly resembles *P. Melongena*, Lam., which is a recent species from the West India islands: it may be distinguished by its shorter figure, by being more ventricose, by the pointed tubercles on the spire, and its shorter and wider canal.

FUSUS HENIKERI.

Testa elongato-fusiformis, gracilis, postice elongato-acuminata, anfractibus plurimis, ventricosis, longitudinaliter costiferis, spiraliter liratis, costis rotundatis, liris acutis; canali elongatâ, extus liratâ, margine interno labii columellaris ruguloso; labii externo intus sulcato.

Remarkable for being distinctly longitudinally ribbed and spirally grooved; the inside of the outer lip is also grooved, and the inner edge of the columellar lip is rugulose.

FUSUS HAITENSIS.

Testa elongato-fusiformis, gracilis, postice elongato-acuminata, anfractibus plurimis, ventricosiusculis, undique spiraliter liratis, liris prominentibus acutis, medianâ duplicatâ majori, longitudinaliter costatis, liris costas decussantibus; canali validâ, liris posticis distinctis, anticis subobsoletis.

Most like *F. Toreuma*, Desh., but distinguished by the central elevated ridge being formed of two lines, and being more prominent than the remainder.

FASCIOLARIA SEMISTRIATA.

Testa oblongo-fusiformis, anfractibus senis, antice posticeque spiraliter striatis, mediane lævibus; striis duabus elevatis prope suturam conspicuis.

This species most nearly resembles *F. fusiformis* of Reeve; it may, however, be easily distinguished, by the middle part of the volutions being free from the spiral striæ.

FASCIOLARIA INTERMEDIA.

Testa oblongo-fusiformis, anfractibus senis, primo lævi papilliformi, secundo, tertio et quarto tuberculatis, cæteris ventricosis, lævibus; canali longiusculo.

A single specimen with a papillary apex, like that of *F. papillosa*, Sow. Tank. Cat.

STROMBUS AMBIGUUS.

Testa ovato-elongata, postice acuminata, transversim dense striata, anfractibus octo, primis transversim costellatis, anticis duobus tuberculiferis, tuberculis parvis, rotundatis; aperturâ latiusculâ, labio externo extus varice distinctâ, intus ruguloso, labio columellari intus postice ruguloso.

Distinguished from *Str. bifrons* by the rugulosities at the posterior inner part of the columellar lip, as well as by the form of the tubercles.

STROMBUS HAITENSIS. PL. IX. fig. 7.

Testa suboblongo-turbinata, transversim sulcata, spirâ pyramidali, acuminatâ, subundulatâ, varicosâ, anfractibus novem, ultimo ad dorsum tuberculato, tuberculorum seriebus duabus, alterâ posticâ, tuberculis subdepresso-acuminatis; alterâ anticâ, tuberculis duobus vel tribus sistente; tuberculo parvo prope labium remoto; aperturâ elongatâ, labii externi crassi margine inflexo.

A species which closely resembles *Str. inermis* of Swainson, from which it may be distinguished by its peculiarly-arranged tubercles.

STROMBUS PROXIMUS. PL. IX. fig. 8.

Testa ovato-oblonga, antice posticeque acuminata, transverse striata, anfractibus novem, posticis transversim costellatis, varicosis, anticis duabus tuberculiferis, tuberculis acuminatis, ultimo nonnunquam seriebus tuberculorum duabus; aperturâ latiusculâ, subexpansâ, intus lævissimâ, canali subreflexo.

This differs from *Str. gracilior*, Sow. (to which species it is most nearly allied), in having the inner part of both lips quite smooth, the outer surface of the two last volutions distinctly striated, and in the first volutions being transversely ribbed and not tuberculated.

STROMBUS BIFRONS. PL. IX. fig. 9.

Testa ovato-oblonga, utrinque acuminata, transversim striata, anfractibus octo, primis transversim costellatis, anticis duobus postice tuberculatis, serie tuberculorum unicâ, tuberculis acuminatis; aperturâ latiusculâ; labio externo extus varice unicâ subdistinctâ intus ruguloso, labio columellari lævissimo.

This species bears some resemblance to *Str. Columba*, but is very easily distinguished.

TRITON SIMILLIMUS.

Testa ovato-elongata, postice acuminata, distorta, varicibus quatuor ad quinque indistinctis, anfractibus octo, liris elevatis clathratis, tuberculiferis ornatis; columellâ profundiuscule excavatâ, ad laterem canalis dentibus rugosâ, callositate postice armatâ; labro subplano, margine interno dentato, dentibus validis, tertio maximo; margine labri externo dentibus mediocribus, continuis; canali subreflexo; anfractûs ultimi parte posticâ internâ dentibus duobus oblongis, magnis.

Nearly related to *Tr. decipiens* of Reeve, but distinguishable by the greater coarseness of the decussating ridges and the tubercles formed at their junction.

TYPHIS ALATUS. PL. X. fig. 4.

Testa ovato-oblonga, subfusiformis, transversim striata, anfractibus senis, quadri-

fariam varicosis, costellis brevibus intermediis; varice ultimo lato, tenui, radiatim striato, canali longiusculo, obtecto.

Distinguished by the tenuity and great extent of the wing-like varix from all known species.

Murex Domingensis. Pl. X. fig. 5.

Testa subovata, utrinque subacuminata, trifariam varicosa, anfractibus senis, longitudinaliter costellatis, spiraliter valide striatis; varicibus prominentibus, rotundatis, marginibus paucispinosis, spinis brevissimis; labio columellari antice ruguloso; canali breviusculâ.

Pyrula Consors.

Testa obovata, ventricosa, lævis, transversim striata; anfractibus quinque, primis tuberculatis, ultimo seriebus duabus ad tribus postice, antice serie solitariâ ornatis; aperturâ oblongâ, latâ; canali lato, brevi; columellâ antice subangulatâ, planulatâ.

This species nearly resembles *P. Melongena*, Lam., which is a recent species from the West India islands: it may be distinguished by its shorter figure, by being more ventricose, by the pointed tubercles on the spire, and its shorter and wider canal.

Fusus Henikeri.

Testa elongato-fusiformis, gracilis, postice elongato-acuminata, anfractibus plurimis, ventricosis, longitudinaliter costiferis, spiraliter liratis, costis rotundatis, liris acutis; canali elongatâ, extus liratâ, margine interno labii columellaris ruguloso; labii externo intus sulcato.

Remarkable for being distinctly longitudinally ribbed and spirally grooved; the inside of the outer lip is also grooved, and the inner edge of the columellar lip is rugulose.

Fusus Haitensis.

Testa elongato-fusiformis, gracilis, postice elongato-acuminata, anfractibus plurimis, ventricosiusculis, undique spiraliter liratis, liris prominentibus acutis, mediana duplicatâ majori, longitudinaliter costatis, liris costas decussantibus; canali validâ, liris posticis distinctis, anticis subobsoletis.

Most like *F. Toreuma*, Desh., but distinguished by the central elevated ridge being formed of two lines, and being more prominent than the remainder.

Fasciolaria semistriata.

Testa oblongo-fusiformis, anfractibus senis, antice posticeque spiraliter striatis, mediane lævibus; striis duabus elevatis prope suturam conspicuis.

This species most nearly resembles *F. fusiformis* of Reeve; it may, however, be easily distinguished, by the middle part of the volutions being free from the spiral striæ.

Fasciolaria intermedia.

Testa oblongo-fusiformis, anfractibus senis, primo lævi papilliformi, secundo, tertio et quarto tuberculatis, cæteris ventricosis, lævibus; canali longiusculo.

A single specimen with a papillary apex, like that of *F. papillosa*, Sow. Tank. Cat.

STROMBUS AMBIGUUS.

Testa ovato-elongata, postice acuminata, transversim dense striata, anfractibus octo, primis transversim costellatis, anticis duobus tuberculiferis, tuberculis parvis, rotundatis; aperturâ latiusculâ, labio externo extus varice distinctâ, intus ruguloso, labio columellari intus postice ruguloso.

Distinguished from *Str. bifrons* by the rugulosities at the posterior inner part of the columellar lip, as well as by the form of the tubercles.

STROMBUS HAITENSIS. PL. IX. fig. 7.

Testa suboblongo-turbinata, transversim sulcata, spirâ pyramidali, acuminatâ, subundulatâ, varicosâ, anfractibus novem, ultimo ad dorsum tuberculato, tuberculorum seriebus duabus, alterâ posticâ, tuberculis subdepresso-acuminatis; alterâ anticâ, tuberculis duobus vel tribus sistente; tuberculo parvo prope labium remoto; aperturâ elongatâ, labii externi crassi margine inflexo.

A species which closely resembles *Str. inermis* of Swainson, from which it may be distinguished by its peculiarly-arranged tubercles.

STROMBUS PROXIMUS. PL. IX. fig. 8.

Testa ovato-oblonga, antice posticeque acuminata, transverse striata, anfractibus novem, posticis transversim costellatis, varicosis, anticis duabus tuberculiferis, tuberculis acuminatis, ultimo nonnunquam seriebus tuberculorum duabus; aperturâ latiusculâ, subexpansâ, intus lævissimâ, canali subreflexo.

This differs from *Str. gracilior*, Sow. (to which species it is most nearly allied), in having the inner part of both lips quite smooth, the outer surface of the two last volutions distinctly striated, and in the first volutions being transversely ribbed and not tuberculated.

STROMBUS BIFRONS. PL. IX. fig. 9.

Testa ovato-oblonga, utrinque acuminata, transversim striata, anfractibus octo, primis transversim costellatis, anticis duobus postice tuberculatis, serie tuberculorum unicâ, tuberculis acuminatis; aperturâ latiusculâ; labio externo extus varice unicâ subdistinctâ intus ruguloso, labio columellari lævissimo.

This species bears some resemblance to *Str. Columba*, but is very easily distinguished.

TRITON SIMILLIMUS.

Testa ovato-elongata, postice acuminata, distorta, varicibus quatuor ad quinque indistinctis, anfractibus octo, liris elevatis clathratis, tuberculiferis ornatis; columellâ profundiuscule excavatâ, ad laterem canalis dentibus rugosâ, callositate postice armatâ; labro subplano, margine interno dentato, dentibus validis, tertio maximo; margine labri externo dentibus mediocribus, continuis; canali subreflexo; anfractûs ultimi parte posticâ internâ dentibus duobus oblongis, magnis.

Nearly related to *Tr. decipiens* of Reeve, but distinguishable by the greater coarseness of the decussating ridges and the tubercles formed at their junction.

TYPHIS ALATUS. PL. X. fig. 4.

Testa ovato-oblonga, subfusiformis, transversim striata, anfractibus senis, quadri-

fariam varicosis, costellis brevibus intermediis; varice ultimo lato, tenui, radiatim striato, canali longiusculo, obtecto.

Distinguished by the tenuity and great extent of the wing-like varix from all known species.

Murex Domingensis. Pl. X. fig. 5.

Testa subovata, utrinque subacuminata, trifariam varicosa, anfractibus senis, longitudinaliter costellatis, spiraliter valide striatis; varicibus prominentibus, rotundatis, marginibus paucispinosis, spinis brevissimis; labio columellari antice ruguloso; canali breviusculâ.

Pyrula Consors.

Testa obovata, ventricosa, lævis, transversim striata; anfractibus quinque, primis tuberculatis, ultimo seriebus duabus ad tribus postice, antice serie solitariâ ornatis; aperturâ oblongâ, latâ; canali lato, brevi; columellâ antice subangulatâ, planulatâ.

This species nearly resembles *P. Melongena*, Lam., which is a recent species from the West India islands: it may be distinguished by its shorter figure, by being more ventricose, by the pointed tubercles on the spire, and its shorter and wider canal.

Fusus Henikeri.

Testa elongato-fusiformis, gracilis, postice elongato-acuminata, anfractibus plurimis, ventricosis, longitudinaliter costiferis, spiraliter liratis, costis rotundatis, liris acutis; canali elongatâ, extus liratâ, margine interno labii columellaris ruguloso; labii externo intus sulcato.

Remarkable for being distinctly longitudinally ribbed and spirally grooved; the inside of the outer lip is also grooved, and the inner edge of the columellar lip is rugulose.

Fusus Haitensis.

Testa elongato-fusiformis, gracilis, postice elongato-acuminata, anfractibus plurimis, ventricosiusculis, undique spiraliter liratis, liris prominentibus acutis, medianâ duplicatâ majori, longitudinaliter costatis, liris costas decussantibus; canali validâ, liris posticis distinctis, anticis subobsoletis.

Most like *F. Toreuma*, Desh., but distinguished by the central elevated ridge being formed of two lines, and being more prominent than the remainder.

Fasciolaria semistriata.

Testa oblongo-fusiformis, anfractibus senis, antice posticeque spiraliter striatis, mediane lævibus; striis duabus elevatis prope suturam conspicuis.

This species most nearly resembles *F. fusiformis* of Reeve; it may, however, be easily distinguished, by the middle part of the volutions being free from the spiral striæ.

Fasciolaria intermedia.

Testa oblongo-fusiformis, anfractibus senis, primo lævi papilliformi, secundo, tertio et quarto tuberculatis, cæteris ventricosis, lævibus; canali longiusculo.

A single specimen with a papillary apex, like that of *F. papillosa*, Sow. Tank. Cat.

Turbinellus validus.

Testa oblongo-subfusiformis, lævis, postice acuminata, antice coarctata, anfractibus 6 ad 8, subventricosis, spiraliter striatis, posticis transversim obtuse costatis, intermediis subtuberculatis, anticis duobus postice tuberculatis; suturâ canaliculatâ, margine levatâ; aperturâ magnâ, canali valido extus striato.

This species somewhat resembles *T. Scolymus*: it differs, however, materially in its general form not being hexagonal; in the suture, whose margin is elevated and with a narrow channel; and in its tubercles, which are small and rounded.

Turbinellus Haitensis.

Testa subtrigona, turbinata, transversim striata, tuberculata, spirâ subdepressâ, subacuminatâ; anfractibus senis, postice anguliferis, ad angulum tuberculiferis, lateribus declivibus; antice seriebus duabus tuberculorum, quarum postica multo major; labio columellari quadriplicato; canali extus subtuberculato.

The flatness of the spire at once distinguishes this from *T. pugillaris*, Lam.

Pleurotoma Henikeri. Pl. X. fig. 6.

Testa elongato-acuminata, crassiuscula, rudis, anfractibus novem, spiraliter liratis, longitudinaliter rotundato-costatis, infra suturam uniliratis, deinde lævibus subconcavis; aperturâ oblongâ, latiusculâ, labio externo valido, crasso, sinu postico distincto, columellari crassiusculo; canali breviusculo, subumbilicato, subreflexo.

In general form this species resembles *Pl. maura*, Sow.; there are, however, several characters by which it may be distinguished.

Pleurotoma venusta. Pl. X. fig. 7.

Testa acuminato-turrita, crassa, anfractibus rotundatis, confertim costellatis, interstitiis transversim liratis, ad suturam subdepressis, labio externo crassiusculo, patulo, sinu postico lato, profundo; canali brevissimo, subrecurvo; ultimi anfractûs tuberculo dorsali oblongo, conspicuo.

In shape this species resembles *Pl. gibbosa* of Kiener and *Pl. pallida* of Sowerby.

Pleurotoma Consors.

Testa elongata, acuminato-turrita, anfractibus postice concavis, lævibus, mediane et antice spiraliter liratis, liris costis longitudinalibus decussantibus granulis formantibus; suturâ undulatâ, lirâ parvâ levatâ anticâ; canali mediocri.

This species bears some general resemblance to *Pl. militaris* of Reeve.

Pleurotoma Haitensis.

Testa turrito-acuminata, elongata, spiraliter striata et lirata, liris in utroque anfractu quatuor, centrali conspicuo, in ultimo anfractu septem, tertio conspicuo sinu distincto; canali longo, oblique lirato; interstitiis linearum incrementi obsolete decussatis.

In general appearance this species resembles *Pl. virgo*: it differs, however, in the circumstance that in *Pl. virgo* the second ridge is generally the one that is decurrent with the notch, whereas in our fossil it is the third; this ridge has also a second line marking its edge.

PLEUROTOMA JAQUENSIS.

Testa fusiformi-turrita, anfractibus 7 ad 8, transversim costatis, postice sublævibus, antice spiraliter striatis; costis validis, rotundatis, striis distinctis supra costas decurrentibus; aperturâ ovatâ, canali breviusculo, lato, extus striato, subrecurvo; suturâ costellâ spirali, undulatâ indutâ.

Aperture and canal about two-fifths the length of the shell. This species is nearly related to *Pl. oblonga*.

CERITHIUM UNISERIALE.

Testa acuminato-turrita, antice ventricosa, anfractibus spiraliter striatis, serie unicâ tuberculorum ornatis, suturâ distinctâ adpressâ, obsolete crenatâ, ultimi anfractûs serie tuberculorum minimorum, sutura serie tuberculorum parvorum ornata; striis spiralibus tenuissimis interruptis.

CERITHIUM PLEBEIUM.

Testa acuminato-turrita, nonnunquam varicosa, anfractibus undecim rectiusculis, spiraliter costatis, costis granosis triseriatis, serie posticâ paululum remotâ; lineâ elevatâ suturæ distinctâ.

SOLARIUM QUADRISERIATUM. PL. X. fig. 8, *a*, *b*, *c*.

Testa orbicularis, depresso-conoidea, anfractibus senis, superne spiraliter granosis, granis in seriebus quatuor confertis; prope marginem sulco valido postico, margine superne infraque minutissime crenulato, infra cingulis plurimis granosis, quorum primus filiformis, minutissime crenulatus, secundus minutissimus, cæteris majoribus; dentibus umbilici crassis.

In the teeth of the umbilicus this species closely resembles *S. granulatum*, Lam.; in all other characters it differs from every known species.

PETALOCONCHUS* DOMINGENSIS. PL. X. fig. 9.

Testa contorta, crassa, tubulo plerumque spirali, anfractibus ad marginem inferiorem angulatis, angulo costulisque longitudinalibus graniferis; costulis nonnullis etiam infra angulum anfractuum graniferis.

This remarkable spiral shell approaches near to *P. sculpturatus* of H. C. Lea, only his species does not appear from his figure to have any granular longitudinal ridges below the angle of the volutions.

NATICA SUBCLAUSA.

Testa obovata, lævis, anfractibus tribus, ultimo maximo, callo umbilicali magno, crasso, umbilicum fere claudente.

In general form this species nearly approaches to *N. Mamilla*; in that species, however, the umbilicus is entirely closed. In another somewhat similar species, which I believe is called *N. Olla* by Valenciennes, the umbilicus is much more open than it is in our fossil.

BULLA GRANOSA. PL. X. fig. 10.

Testa ovato-subglobosa, ventricosa, tenuis, transversim striata, striis paucis, distinctis, lineas incrementi decussatis, graniferis; columellâ late marginatâ, sulco postico profundo; spirâ inclusâ.

Nearly like *B. hydatis* in form.

* *Petaloconchus* of H. C. Lea, in Trans. of Amer. Phil. Soc. vol. ix. p. 229. pl. 34. f. 3.

Bulla paupercula.

Testa ovato-oblonga, mediane subcoarctata, lævis, antice transversim striata, labio columellari antice incrassato.

Cardium Haitense. Pl. X. fig. 11.

Testa oblique subovata gibbosa, radiatim costata, lateribus brevibus, costis quatuor et viginti, quadratis, graniferis, interstitiis creberrime rugulosis; angulo postico rotundato ex umbone ad marginem inferiorem posticam decurrente.

Very like *C. subovale* of Brod. and Sow., but wider, and distinguished further by the squareness of the ribs. The grains on the ribs constitute another remarkable character, in which this differs from *C. subovale*.

Arca Patricia.

Testa æquivalvis, quadrata, infra rotundata, crassissima, lateribus superne subauriculatis; margine inferiori rotundato; latere postico paululum extenso; superficie radiatim costatâ, costellarum lateribus superne angulatis, costellis anticis obsolete granosis; serie dentium cardinis angustâ, postice recurvâ.

Distinguished from *A. grandis* by its form, which is much more rounded at the inferior margin; by the angularity of its radiating ribs, which are moreover rather more numerous; and by the narrowness of the line formed by the row of hinge-teeth, and the recurved posterior termination of the same row.

Arca consobrina. Pl. X. fig. 12.

Testa oblonga, obliqua, æquivalvis, radiatim costata, lateribus superne angulatis, antico infra rotundato, postico rotundato-angulato; costis angustis, numerosis, plerumque quadratis, et decussatis, ad basin sulco tenui divisis, posticis fere lævibus, planulatis; areâ cardinali latiusculâ.

In general appearance this resembles *A. labiosa*; the cardinal area is, however, much larger, and the ribs, except some of the posterior, are decussated. Judging from a cast, the two valves appear to be equal.

Pecten Thetidis.

Testa orbicularis, tumida, radiatim costata, costarum marginibus quadratis, ad utrumque latus squamuliferis, squamulis minutissimis, interstitiis rugulosis; auribus inæqualibus, radiatim costatis, costellis squamulosis.

Pecten inæqualis.

Testa suborbicularis, tumidiuscula, costellis radiantibus 19, rotundatis, lævibus, subdistantibus, superne lineis decussantibus hic illic sparsim notatis; interstitiis rotundatis, lævibus, æquidistantibus; alterius valvæ costellis angustioribus interstitiis latioribus, lævissimis; auribus inæqualibus, radiatim costellatis.

Pecten oxygonum.

Testa suborbicularis, subobliqua, tumida, costellis radiantibus 19, superne acutangulis, interstitiisque æqualibus lineis incrementi concinne decussatis; auribus inæqualibus, lævibus, radiatim costellatis, costellis tenuissimis.

Fossels from San Domingo.

J.D.C. Sowerby

Fossils from San Domingo.

PECTUNCULUS ACUTICOSTATUS. PL. X. fig. 13.

Testa suborbicularis, subobliqua, postice subangulata, radiatim multicostata, costis tenuibus, sulcisque angulatis; areâ cardinali bifariam tenuiter sulcatâ, dentibus cardinalibus ad utrumque latus numerosis, confertis.

A small species, distinguished by its subangular form posteriorly, its angular radiating ribs, and its numerous close-set hinge-teeth. It approaches in general form to *P. Pallium*, Reeve.

OSTREA HAITENSIS.

Testa oblonga, crassa, plicata, plicis paucis (senis ad septenis), magnis, undulatis, subsquamosis, squamis nonnunquam subtubulosis; limbo interno omnino glabro.

This species appears to be related to *O. imbricata*, Lam.; it differs, however, in its general form, which is oblong and not orbicular, and in the number of external radiating folds, which are only six or seven in our shell.

SPONDYLUS BIFRONS.

Testa subregularis, rotundata, ventricosa, margine latiusculo, valide denticulato; extus radiatim costata, costis 5 ad 6 spiniferis; areâ cardinali alterius valvæ angustissimâ, alterius latiori.

Nearest to *S. imperialis*, easily distinguishable by the area of one valve being very narrow, and that of the other being rather broader, though still narrow.

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2. *Observations on the Silurian Strata of the* SOUTH-EAST *of* SCOTLAND. By JAMES NICOL, F.R.S.E., F.G.S., Assistant-Secretary Geol. Soc.

DURING a visit to the south of Scotland last autumn I collected some fossils from the older rocks of that district, which appear interesting as adding another link to the chain of evidence by which the true age of these deposits may be ascertained. Taken in connection with the fossils formerly noticed* and with those procured by Mr. Moore in Wigtonshire†, they may be regarded as rendering the Lower Silurian age of one part of these beds almost certain, so that the connection of the rocks and mountain-chains of this portion of Britain with those of other countries may now be so far traced out.

The fossils which Mr. Salter last year kindly determined were chiefly procured from the only bed of limestone known in the Silurian rocks of the south-east of Scotland. My hopes of obtaining better or more characteristic specimens from that locality were disappointed, and not even a single new form was discovered after a careful search. Indeed, the highly crystalline texture of the limestone, probably occasioned by a mass of trap with which it is always associated, renders it very improbable that this bed will ever add much to our knowledge of the beings existing in the seas in which it was deposited.

My researches in the slate rocks were more successful, especially in the Grieston quarry near Traquair. In this place the rocks consist of clay-slate, sometimes passing into a fine greywacke, and are wrought

* Quart. Geol. Journ. vol. iv. p. 205. † Ib. vol. v. p. 7.

for a coarse kind of roofing-slate. The strata are thin and very regular, and dip at 65° to N. 51° W. of true direction. No cleavage appears in these beds, and the slates are formed by splitting the mass along the laminæ of deposition, as the position of the fossils clearly proves. The rock is intersected by two sets of open fissures, of which one series dip at 85° to W. 45° S.; and another at the same angle to E. 5° N. The amount of dip and the direction vary considerably in both, the second being more irregular; the edges of the beds along it are also broken, rubbed and striated, as if the masses of slate had been pushed over each other. The surfaces of some of the beds are very curiously marked, as the specimens on the table will show. Some of these resemble the ripple-mark common on sandstones, and others are not unlike the impression of some organic body, but the whole are more probably concretionary and entirely mineral in character. In some beds, concretions partly calcareous, partly ferruginous occur, the latter much resembling moss or decaying wood, but showing no trace of organization when examined by the microscope. A few feet above these graptolite beds there is a thin irregular layer from half an inch to two inches thick, of a granular rock containing fragments of steatite and mica of a pinchbeck brown colour.

In this quarry at least two beds containing fossils occur. The upper one is a fine-grained greywacke, the surface of which is almost covered by the *Graptolites Sedgwickii*, but the specimens, from the nature of the stone, are rarely well-preserved. About ten feet lower a bed of slate has been lately opened containing fossils of this genus in great abundance, which are found not only on the surface, but also through a considerable thickness of the slate. This circumstance, taken in connexion with the finer materials of the matrix and the beautiful state of preservation of the imbedded fossils, shows that these have lived on the spot, whereas those in the higher bed have more probably been drifted to this place by a stronger current. About seventy to eighty feet higher a third bed containing graptolites is known, but as a slip intervenes, it may probably be one of those already mentioned. At least six species of graptolites occur in this locality, as enumerated in the following list:—

Graptolites Sedgwickii, *Portlock*.
—— distans, *Portlock*.
—— tenuis, *Portlock*.
Graptolites convolutus, *Hisinger*.
—— ludensis, *Murchison*.
—— griestoniensis, new species.

The last seems very distinct from any species formerly described, and is well-characterized by the oblong form of its polyp-cells which are closely appressed to the axis. The first four of these species were found by Colonel Portlock in the Lower Silurian slates of Desertcreat in Tyrone; and the third, *G. tenuis*, also by Mr. James Hall in the black slates of the Hudson River group of New York, which is considered by Mr. Sharpe and others as the equivalent of the Lower Silurian deposits of England. The *G. ludensis*, though originally discovered by Sir Roderick Murchison* in a higher part of the series, extends down into the Llandeilo flags. The *G. convolutus*, first described by Hisinger from the clay-slates of Sweden, has been since

* Silurian System, p. 694, pl. xxvi. fig. 1, 1*a*.

found in Ireland. These new discoveries therefore form a very satisfactory confirmation of Mr. Salter's identification of the trilobites and shells of the Wrae limestone with those of the Tyrone beds.

The Grieston slates often contain small fragments of anthracite, and a considerable amount of this substance was found some years ago in the Cadon Bank, a hill about a mile distant, forming an irregular bed or vein among the greywacke strata. It is very impure, and burns with much difficulty, so that even after being exposed for some time to the flame of the blowpipe, the form of the mass is little altered. The strata in which it occurs have been much disturbed and affected by igneous action, being intersected in one place by a vein of amygdaloidal greenstone, whilst the top of the hill is formed of red felspar porphyry. In the ashes of this anthracite I have observed tubular fibres under the microscope, so that no doubt can be entertained of its organic nature. It thus proves that plants existed even in these early periods, in sufficient abundance to produce thin beds or seams of coal. In the Grieston slates some markings occur which may have been algæ, but the structure shown in the ashes of the anthracite would rather indicate a higher class of vegetation.

About three miles to the north-east of the Grieston and nearly in the strike of the beds, I also succeeded in obtaining a few specimens of fossils. They were found on Torysknies, a hill belonging to that group, in which, as the map will show, igneous action has chiefly prevailed in this district; the felspar porphyries decreasing in amount with the distance from it. The summit of the hill is formed of porphyry, but the declivities consist of hardened slates, often almost crystalline in texture and closely resembling clinkstone. They contain much iron, and seem so altered by the connected igneous rocks, that the preservation of fossils was very unexpected, and proves the extreme difficulty of destroying organic forms when they are once imbedded in the solid stone.

The discovery of these remains in the prolongation of the former strata, shows that the fossiliferous beds are probably persistent for considerable distances, and may thus aid us in working out the succession of these accumulations. It was also interesting on another account. About 500 yards south of the Grieston slates, a bed of red felspar porphyry is seen running nearly parallel to the slates, and may be traced in the same position relative to their outcrop for about a mile westward. A similar rock occurs at intervals for nearly four miles in the same line, but seems to disappear with all the rocks of this class before reaching the valley of the Yarrow. On the east I have traced this, or a similar vein, at short intervals, cropping out on the sides of the hills or in the beds of the streams to a point north of that where the graptolites occur: at this place, however, the vein appears to have divided into two beds about fifty yards apart. This vein seems thus continuous for nearly eight miles in one direction, and runs generally parallel to the strata. This parallelism is, however, not complete, as it is in one place to the south, in the other to the north of the fossiliferous beds, and has therefore intersected them in the interval*.

* A still stronger proof that some at least of these felspar rocks are not contemporaneous with the strata, but truly injected masses or dykes, is furnished by

In Thornielee slate quarry in Selkirkshire, on the bank of the Tweed, about six miles below Grieston, a few specimens of two of the same species of graptolites were found. The beds here dip at 82° to S. 50° E., or in the opposite direction to those at the former place, and also lie considerably south of their strike, so that they may thus form merely the other side of an anticlinal axis. They have, however, a different mineralogical aspect, being often of a brownish red colour, so that I am more inclined to consider them distinct. Besides the *G. convolutus* and the *G. ludensis*, there is probably a foliaceous species of this genus, which is not seen in the Grieston slates. In the latter also annelid impressions are rare, whereas in Thornielee quarry they are very abundant, thus strengthening the view that these two localities belong to distinct parts of the series. Some of these worm-like impressions much resemble the species figured in the 'Silurian System' of Sir Roderick Murchison, and may even be identical; but it is difficult to obtain certainty in regard to forms presenting so few well-defined characters, that even their animal nature may be doubted. The regularity of the folds, with the apparent impression of feet or setæ on the margin, seem to show that they are organic, and rather an impression of the body of the animal itself than a mere trail left in the soft mud*. Similar fossils occur in the Tyrone beds, which, as Colonel Portlock states†, "exhibit on their surfaces those markings like the stems of algæ and the tortuous labyrinths of annelids, so common to indurated muddy or sandy strata." They have also been observed in the older palæozoic rocks of North America, and several, not unlike those from Scotland, are figured by Mr. Emmons from his so-called Taconic group. Thus far they confirm the view now given of the age and connexion of these rocks; though as similar rude memorials of extinct life occur in formations of every age, they perhaps rather indicate similarity of conditions during deposition than identity of age‡.

From the whole facts noticed in this and a former paper, there can be little doubt that the slates and greywackes of this part of Scotland belong to the Lower Silurian period, and are probably the equivalents of the Llandeilo flags of Wales. Judging from the specimens of the older Welsh rocks contained in the Museum of the Society, these

several veins that intersect the strata at a considerable angle. Veins of this kind may be seen in Priesthope, though most of them in that locality conform to the bedding. A vein near the source of the Leithen with a direction to S. 50° E. by compass, whilst the strike of the strata is nearly from E. to W., also confirms this view. In a mass of vertical, or nearly vertical strata, the line of least resistance to the escape of an igneous rock would of course be between the beds.

* Some of these impressions penetrate a considerable thickness of the slate, even as much as one-fourth of an inch. This shows that the animal has rather lived in the mud than moved through it. The peculiar arrangement in the mass below might arise from the worm gradually raising its body towards the surface by a kind of undulating motion as the soft mud accumulated and deprived it of access to the water.

† Geol. Report on Londonderry, p. 230.

‡ Similar forms are common in rocks of the coal formation and the lias, and specimens from both are preserved in the Museum of the Society. Sir Charles Lyell recently presented others from modern mud deposits in the Bay of Fundy. See Quart. Geol. Journ. vol. v. p. 344.

flags are also the most closely allied in mineral character to the Silurian formations of the region now considered. The coarse white siliceous grits common among the Caradoc sandstones are unknown, so far as I have observed, among the old rocks in the south-east of Scotland. The only beds that approximate to these grits in mineral aspect are some in the south of Roxburghshire, and thus in what is probably a newer part of the series (perhaps equivalents of some part of the upper Ludlow rocks?). The most important peculiarity of the Welsh rocks, is the great abundance of organic life which they exhibit when compared with the few traces found in the north. They seem also to differ somewhat in mineral composition, containing a much greater amount of felspathous and apparently volcanic materials than are seen in the Scottish strata. Even mineral and metallic products are, with a few exceptions, rarer in the latter deposits;—probably consequences or at least indications of a less frequent contemporaneous igneous action. It is an interesting question how far we can connect the more or less abundance of life in these ancient seas with the variety of mineral ingredients thrown into their waters by volcanos existing at the time*.

The Silurian beds discovered by Colonel Portlock in Tyrone, are, however, the nearest equivalents of those now described. The mineral characters of the rocks do not appear very different, and in both countries they are characterized by the comparative scarcity of calcareous matter. The Irish strata also lie in the direct continuation of the northern part of the Scottish mountains, from the termination of which, near Portpatrick, they are only separated by an interval of 100 miles. From Peebles-shire the distance is nearly 200 miles, and the agreement in organic remains is perhaps closer than might have been expected, more especially as not more than three of the Peebles-shire fossils appear among those collected by Mr. Moore in an intermediate locality. It is also worthy of notice, that whilst the Grieston graptolites have only serratures on one side of the axis, those from Wigtonshire generally show these on both sides: hence the latter probably belong to another part of the series, and perhaps correspond with the patch of Silurian schists discovered in Fermanagh in Ireland, which contain the *G. pristis* and other foliaceous species like those in Wigton. These strata lie further south than the Tyrone beds with which the Peebles-shire deposits have most affinity, and Colonel Portlock† also places them in a higher part of the series. In both countries therefore, the older rocks occur on the north, the newer on the south, a coincidence confirming the classification of the Scottish deposits here proposed. In another point, the geological history of the two districts also cor-

* The contemporaneous traps of the English Silurian deposits are described by Sir R. I. Murchison in his great work on this formation. See Silurian System, pp. 75, 269, 401, &c.; comp. Journ. Geol. Soc. vol. iii. p. 171–175. In this place the author ascribes the comparative rarity of animal life in certain portions of the English strata, to the intense igneous action which accompanied their deposition. The opposition to the view in the text is only apparent, as the eruptions which in their immediate vicinity and during the time of their most violent action were sufficient to destroy life, might yet be favourable to its development during the intervals of repose and at greater distances, by introducing more calcareous and other substances into the water.

† Report on Lond. p. 232.

responds. Colonel Portlock draws attention to the strongly marked line of demarcation between the fauna of the ancient rocks in this part of Ireland and that of the formations which succeed them. "In fact," he says, "there is here no such intermediate formation, in a fossil sense, as the Devonian system; that is, there is no formation in which fossils peculiar to itself are commingled with a large percentage of those belonging to the Silurian on the one hand, and the carboniferous on the other*." And this may with equal truth be asserted of the south of Scotland, where the break both physical and palæontological, between the Silurian and the next higher formation, is remarkably distinct, and indicates a long period during which no deposits have been here formed. It was probably during this interval that the rich ichthyolitic beds of Perthshire, Forfarshire and the north of Scotland were accumulated. It is in the latter localities therefore that a transition downwards from the well-known carboniferous and old red sandstone forms of life into those of the Silurian beds must be sought, rather than on the southern side of the synclinal trough†.

Any estimate of the thickness of these Silurian deposits must evidently be very imperfect, as the thick covering of detritus renders it almost impossible to work out continuous sections. The difficulty is increased by the principal rivers flowing generally along the strike of the beds, so that those transverse gorges in which full displays of the stratification might be expected to occur are very rare. The following calculations, therefore, are merely hypothetical, and intended rather to stimulate than to satisfy inquiry. Assuming that the Thornielee slates belong to a different part of the series from those of the Grieston, we have in this part of Scotland three distinct bands of fossiliferous rocks running from south-west to north-east in nearly parallel lines. The most northerly is the Wrae limestone, which, in a country where lime is of so much value, we may well believe would have been known had it again cropped out to the south. It can be certainly traced for more than a mile, having been quarried on the south side of the Tweed near Drumelzier Castle, where it is also accompanied by trap. A similar trap rock is seen twelve miles east in the Eddleston river associated with an impure limestone formerly quarried, which probably forms the continuation of this bed. The distance of these three bands from each other, measured on the map, at right angles to their strike, is six miles from the first to the second, and four miles from the second to the third, or ten miles in all. Allowing for the inclination of the strata, supposed to dip at an average angle of 50°, which is much below the reality, the beds included in these two zones will have a thickness of about 40,000 feet, or of 24,000 feet in the more northern one alone. As this is exclusive of the whole mass of more recent beds on the south, the Silurian formations of Scotland at least equal those of other countries in the amount of accumulations, however inferior they may be in abundance of organic remains.

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* Report on Lond. p. 233.

† The "enormous aggregate thickness of the former deposits" was noticed twenty years ago by Prof. Sedgwick and Sir R. I. Murchison. See Trans. Geol. Soc., 2nd Series, vol. iii. p. 141.

In his Note on the most ancient systems of mountains in Europe*, M. Élie de Beaumont includes the southern mountains of Scotland in his Westmoreland and Hundsrück system, though with some hesitation from uncertainty as to the age of the strata and their mean direction. The former difficulty may now be regarded as removed by the fossils collected by Mr. Moore and myself in such distant parts of the chain, and it thus seems worth while to inquire how far the general direction of the beds coincides with that which he assigns to this system. Among a large number of observations in Peebles-shire and the neighbouring counties, only sixty-six were sufficiently precise to be used for this purpose. With two exceptions, probably accidental, the whole of these fall in an arc of 65°, or little more than one-third the circle. Thirty-five or more than a half dip to the north, thirteen or one-fifth are vertical, and the remainder, eighteen in number, dip south, as shown in fig. 1, in which the Roman numerals mark the number of beds, when more than one, corresponding to each line. The mean of the whole is E. 35° 10′ N., or about 9° north of the magnetic east. According to M. É. de Beaumont's calculation, the direction of the system, to which he refers this chain, is in this place

Fig. 1.—*Direction of Silurian Strata in the South-East of Scotland.*

* Bulletin de la Soc. Géol. de France, tom. iv. p. 917.

about E. 40° N., differing 5° from the mean of the observations. He also ascribes the upheaval of the Grampians to the same great convulsion; and it is remarkable that the narrow zone of clay-slate, extending from Stonehaven to Arran, has for the greater part of its course a direction of E. 36° N., almost identical with the mean of the observations in the south. This band of slate may thus form the continuation of the Silurian beds on the south, rising up on the other side of the synclinal valley in which the carboniferous strata of Scotland have been deposited. The mineral character of the rocks is not opposed to this view; and though no fossils are known in the northern slates, yet in Glen Halmidel in Arran I found spheroidal bodies similar to some very common in Peebles-shire, and which are probably organic, perhaps casts of a species of trilobite.

The direction of these chains is thus not very different from that which the theory would require. The elevation of this system is placed by the distinguished author in the interval between the close of the Silurian and the commencement of the old red sandstone deposits. The latter were formerly* shown to rest unconformably on the edges of the upturned Silurian strata, and also to fill valleys excavated in them subsequent to their elevation. This would carry back the formation of the chain to a period much anterior to the deposition of the sandstone; but as this rock in the south of Scotland should perhaps be rather associated with the carboniferous than with the true Devonian beds of England, an interval of sufficient duration for the various changes, which the strata have evidently undergone before they were covered up by the superior beds, may thus be obtained.

But although the general direction of the strata and the period of their formation do not differ much from that required, there are other facts in the physical structure of this part of Scotland less favourable to this ingenious theory. The Pentland hills, which have undoubtedly been formed subsequent to the deposition of the old red sandstone, or rather of the coal-measures, have a direction of E. 40° N., thus agreeing exactly with the line assigned to the Westmoreland system. The same direction is reproduced in many of the ridges in the coal-field of the Lothians, and also in the trap rocks of Fife and the Ochils. In these instances we have parallelism of direction without identity of age. On the other hand, the Cheviots on the south probably coincide in age with the Pentlands, and also in their general direction; but the porphyry rocks constituting their eastern and highest portion form ridges running N.N.E., and thus vary much from the direction of the chain of which they form a chief part, and also from the system of the North of England, with which they should be closely related in time. The structure of this part of Scotland thus confirms the objections to this theory which Sir Henry de la Beche long ago derived from the lines of elevation observed in the south of England†.

* Quart. Journ. Geol. Soc. vol. iv. p. 199.

† Geol. Manual, 3rd edit. p. 489. M. É. de Beaumont indeed states that there is a tendency in the older lines of elevation to influence the more recent elevations in their vicinity. This, however, so far from removing the objection, admits its truth, and consequently that parallelism in direction, even in neighbouring mountain-chains, is no proof of identity in the time of their elevation.

When we contrast the decided unconformity that always appears in Scotland between the Silurian strata and the formations that rest on them, with the perfect parallelism which has been shown to exist*, in the typical region, between deposits of the same age and the overlying old red and carboniferous rocks, the argument becomes still stronger. With such proofs that these ancient disturbances are merely local, and have not affected all the rocks of one age even in the same country or limited district, we can hardly be expected to believe that their influence has extended over the whole of Europe, and even into the more distant regions of Asia and America.

The dip of the strata in this range of mountains is far less regular, either in amount or direction, than their line of strike. On laying down, however, my observations on the map, it appears that towards the northern margin of the Silurian rocks, the dip is generally northwards, whereas as we proceed south a change takes place, and the dip is more frequently to the south. Though there are numerous exceptions, still this fact indicates the occurrence in this part of the chain of an anticlinal axis over which the beds have been folded. Taken generally, this axis will pass from the group of felspar porphyry hills east of Inverleithen to Loch Skene north of Moffat, where igneous rocks also abound. It thus runs along some of the highest mountains south of the Forth; and the mineral springs at the localities just named are probably connected with this line of ancient igneous action. Its general direction is considerably more to the north of east than the average deduced for the strata.

The position of this axis of elevation so near the northern boundary of the Silurian rocks is a point of much interest, from its apparent connexion with some of the most remarkable physical peculiarities of the country. On examining a geological map of Scotland it will be seen that the boundary between the red sandstone and the Silurian formations on the south is very irregular, the newer deposits forming many indentations in the older. It was thence inferred that the red sandstone had been deposited in valleys eroded in the greywacke rocks at a very early period†. The northern margin presents a different outline. The border there is for great distances nearly a straight line, with few sinuosities. Thus from the trap hills at the sources of the Nith, the line of junction runs almost direct to Howgate near Pennycuik, where it bends slightly to the south, but soon resumes a rectilinear direction towards the north-east to the coast at Dunglass, where it again curves round to the south. Along this line, especially towards the east, the junction of the two formations is marked by a range of hills composed of highly inclined Silurian strata, against which the red sandstone and carboniferous rocks abut in nearly horizontal beds. In some places this appearance is concealed by the igneous formations, especially those connected with Tinto and the Pentlands, but to the south of Edinburgh and along the base of the Lammermuirs it is very distinctly marked. In many places the close

* See Murchison's Silurian System, chap. xlii. p. 568, &c., where the inconsistency of this fact with the theory of M. É. de Beaumont is very clearly explained.

† Journ. of Geol. Soc. vol. iv. p. 200.

resemblance of the steep slope of the greywacke hills to a sea cliff, somewhat softened by degradation in the long lapse of ages, can scarcely be overlooked by the most careless observer.

And such, I believe, has been the origin of the peculiar features of this boundary-line. The Silurian strata evidently extend much farther north below the more recent deposits than their boundary on the map. This is proved by the fragments, covered unconformably by the old conglomerates and sandstones, which are exposed at several points in the Pentland hills where the deeper masses have been forced up by the igneous rocks in that chain. Such an extension of the Silurian beds is also required to balance, as it were, the southern side of the anticlinal arch, stretching down to the border of England. Hence I conclude, that whilst the southern half of the greywacke rocks was being cut into valleys by river action, the northern margin was exposed to the wasting influence of an open sea, which has planed down that rocky bed on which the newer formations of the central trough of Scotland have been deposited. It has only been near the conclusion of the Devonian period that conditions were again established in the southern part of the central valley of Scotland* permitting detritus to accumulate round the ancient shores. This accumulation has then gone on continuously during the whole carboniferous period—red sandstones passing gradually into white, these becoming mixed with shales and then with limestones, as the waters freed from the iron-peroxide became more favourable to the growth of corals and crinoids. Later the calcareous deposits decrease in abundance, and shales and sandstones alternate with seams of coal. During this period the land must have been alternately above and below water, the upright trees seen in many places having grown during the former; the large trunks, forty feet long or more, exposed in the sandstone quarries near Edinburgh, having been drifted into the basin during the intervals of submergence.

The influence of these ancient revolutions on the actual physical geography of the country, particularly the direction of river drainage, deserves notice. On drawing a line along the watershed of the mountain chain, separating the rivers that flow south from those that reach the sea on the north of the axis, it is seen that the latter are comparatively insignificant. The division-line falls either very near, or even beyond, the northern boundary of the chain and of the Silurian rocks. Many of the streams that rise in the newer formations of the central district intersect the whole mass of older deposits on their way to the sea. Thus the Nith has its source in the coal formation of Ayrshire, within twelve miles of the Firth of Clyde, but turns south and falls into the Solway, after passing through the whole ridge of Silurian mountains, elevated in many points from 2000 to 3000 feet above the sea. Further west, some of the smaller streams, as the Cree and Ken, illustrate the same peculiarity; and on the east, the Lyne and other

* On the north side of this trough or valley, in Perth, Forfar, and Kincardine shires, these deposits have begun much earlier. This is shown by the great extent of the old red sandstone in these counties compared to its limited development in Ayrshire and the Lothians.

tributaries of the Tweed follow a course apparently no less devious. The Clyde alone pursues an opposite direction, but many physical phænomena show that its upper waters formerly joined the Tweed by the low valley near Biggar, and hence even this exception is of modern date, and consequent on some of the most recent revolutions in this district. Thus almost the entire drainage of this mountain-chain flows to one side, so that all its larger river-basins open out to the south. The greater number too of the most elevated mountain-summits range along the northern margin, whilst on the south there are many low hills and undulating ridges. Hence the southern valleys are wider and blend more gradually with the plains than those on the north, where the streams often flow through narrow ravines, or deep notches, cut, as it were, in the steep wall of rock forming the ancient sea cliff. The Gladhouse south of Edinburgh, the Herriot near Dunglass, and the singular ravine crossed by the Peas Bridge at a height of 123 feet, but in other places 150 feet deep and only 50 broad, are good illustrations of this peculiarity.

The line of coast south of Dunglass, where Hutton, Playfair and Hall found many of the most convincing illustrations of those great principles of physical geology which they laboured to establish, still exhibits many remarkable traces of this old Silurian beach-line. From the rocky promontory of Fast Castle, the coast trends westward in a series of bold cliffs, fenced by large fragments and outlying points of greywacke. Near Fala-bank it bends more to the north, and the red sandstone appears on the shore, dipping north-east at 25°, and folded in flat curves round the projecting masses of nearly vertical Silurian strata that project at intervals. The sandstone apparently retains its original position, the dip being due to deposition on a sloping bottom, and not to elevation; and hence, in following the beds along the coast, they become more and more nearly horizontal. It is highly interesting to observe the sea gradually washing away the sandstone and exposing the ancient beach on which its waves beat so many ages before.

Notes on the Fossils.

GRAPTOLITES GRIESTONIENSIS. Fig. 2.

I have given this name to the new species from the locality where it occurs. The characters mentioned above, "the oblong serratures closely appressed to the stalk," readily distinguish it from any other I have seen described. Each of these serratures has a raised margin dividing it from the axis and from the one that succeeds it upwards. The serratures and axis are about equal in breadth, and together measure $\frac{1}{20}$ inch or under. The length of some fragments is 6 to 8 inches. In fig. 2, *a* is the natural size; *b*, magnified.

Graptolites convolutus, Hisinger.

In some specimens, probably young, the axis is very narrow compared to the length of the serrations, being little more than a mere line. In other specimens the axis becomes broader and shows a depressed line along the middle. This relative thickening and increase of the axis with age has already been noticed by Geinitz*. In some, perhaps very old varieties of this species, the axis is much less curved, and the serratures much shorter. They form merely a series of very obtuse and wide teeth, scarcely projecting beyond the margin. This may form a distinct species; but the variations evidently produced by age, or from the manner of imbedding in the stone, as seen in different parts of the same specimen, show that much caution is required in such distinctions.

Graptolites ludensis, Murchison.

The specimens agree very well with the figure given in the 'Silurian System†.' The most important difference is in the more rounded, almost club-shaped form of the ends of the serratures in the fossils from Peebles-shire. This probably arises from the specimens being in a more perfect state of preservation. In some of the larger specimens both of this species and of the *G. Sedgwickii*, Portlock, the stem near the root is narrow and almost destitute of serratures, but becomes broader and the serratures very distinct as it ascends. Where also the back of the specimen only is exposed, the serratures may be wholly concealed, so that it appears entirely destitute of these appendages, and such a fragment might readily be taken for a new species. Where the opposite side again is turned to the spectator the serratures are pressed flat, and appear like broad lobes divided by narrow depressions, giving the stalk a jointed appearance. Where the back is well-seen, it is marked by a fine groove running along its centre. Some of our specimens are from 10 to 12 inches long, though imperfect at both ends.

Graptolites laxus.

The foliaceous species from Thornielee, mentioned above, somewhat resembles the *G. pristis*, Hisinger, but the axis is much narrower, and the serratures longer in proportion to their breadth (or length to breadth rather more than 2 : 1). They are also separated by an interval equal to their own width, or even more, a character not seen in any other foliaceous species figured. In this respect it differs so much from the general aspect of the genus, and so closely resembles some plants of the moss-tribe (*Hypnum*), as to render its real character doubtful. If a true graptolite, it seems undoubtedly a new

* Leonhard and Bronn's Jahrbuch für 1842, p. 701. The *G. spiralis* of Geinitz seems identical with the *G. convolutus*, Hisinger.

† Plate 26, figs. 1 and 1*a*. In this work the importance of these fossils, as distinguishing different parts of the Silurian formations, was first made known to geologists. See pp. 206, 694.

species, to which the above name may be given from its most remarkable character.

The true nature of these remains seems still rather uncertain. Schlotheim described them as Orthoceratites, and in his figure a central siphon is represented, and the stem seems composed of distinct cups or joints*. No indication of either of these characters is seen in the most perfect of our specimens, so that we almost doubt whether his fossil belongs to the same class. Other geologists have described them as fucoids. In the 'Silurian System' they are classed as Polyparia, which seems now the opinion generally received. Some of our specimens have left merely a dark, perhaps carbonaceous impression on the slate; others show a cartilaginous or horny texture. In several specimens the slate is discoloured for some distance on each side, and shows minute scales of carbonate of lime, as if the more perishable parts of the animal had extended thus far. It is thus doubtful whether these remains have all belonged to animals of one class; and whether some of them may not rather have been internal organs, than the external axis of a variety of polypifer?

MAY 30, 1849.

P. Martin Duncan, Esq., M.D., and J. Lane Oldham, Esq., were elected Fellows of the Society.

The following communication was then read:—

On the Distribution of the Superficial Detritus of the ALPS, *as compared with that of* NORTHERN EUROPE. By Sir RODERICK IMPEY MURCHISON, F.R.S. G.S. L.S., Hon. Mem. R.S. Ed., R.I. Ac., Mem. Imp. Ac. Sc. St. Pet., Corr. Mem. Ac. France, Berlin, Turin, &c. &c.

[ABSTRACT.]

REFERRING to his previous memoir upon the structure of the Alps and the changes which those mountains underwent, the author calls attention to the fact, that as during the formation of the molasse and nagelflue a warmer climate prevailed, so after the upheaval of those rocks an entire change took place, as proved by the uplifted edges of such tertiary accumulations being surmounted by vast masses of horizontally-stratified alluvia, the forms of whose materials testify that they were deposited under water. The warm period, in short, had passed away and the pine had replaced the palm upon the adjacent lands, before a glacier was formed in the Alps or a single erratic block was translated.

Though awarding great praise to the labours of Venetz, Charpentier and Agassiz, which have shed much light on glaciers, and particularly to the work of Forbes for clearly expounding the laws which

* Petrefactenkunde, Nachtrage, p. 56, tab. 8. fig. 3.

regulate their movement, Sir Roderick conceives, that the physical phenomena of the Alps and Jura compel the geologist to restrict the former extension of the Alpine glaciers within infinitely less bounds than have been assigned to them by those authors.

True old glacier moraines may, he thinks, be always distinguished, on the one hand, from the ancient alluvia, and on the other from tumultuous accumulations of gravel, boulders and far-transported erratic blocks, as well as from all other subsequent detritus resulting from various causes which have affected the surface. He first shews, from the remnants of the old water-worn alluvia which rise to considerable heights on the sides of the valleys, that in the earliest period of the formation of the Alpine glaciers, water, whether salt, brackish or fresh, entered far into the recesses of these mountains, which were then at a considerably lower level, *i. e.* not less, perhaps, than 2500 or 3000 feet below their present altitude.

He next appeals to the existing evidences in the range of Mont Blanc to show, that as each glacier is formed in a *transverse* upper depression, and is separated from its icy neighbour by an intervening ridge, so by their movement such separate glaciers have always protruded their moraines across the adjacent longitudinal valleys into which they descended—and never united to form one grand stream of ice in the valley below. To prove this, it is affirmed that there are no traces of lateral moraines on the sides of the adjacent main valleys, whether on the side of the great ridge from whence the separate glaciers issued or on the opposite side of such main valley, which must have been the case if a large mass of glacier ice had ever descended it. On the contrary, examples of the transport of moraines and blocks *across* such *main* or *longitudinal* depressions are cited from the valley of Chamonix on the one flank and from the Allée Blanche and Val Ferret on the other or south side of the chain of Mont Blanc. Another proof is seen in the ancient moraine of the Glacier Neuva, the uppermost of the valley of the Drance; and a still stronger case is the great chaotic pile of protogine blocks accumulated on the Plan y Bœuf, 5800 French feet above the sea, which have evidently been translated right across the present deep valley of the Drance, from the opposite lofty glacier of Salenon.

Having thus shown that not even the upper longitudinal and flanking valleys around Mont Blanc were ever filled with general ice-streams, the author has no difficulty in demonstrating that all the great trunk or lower valleys of the Arve, the Doire, and the Rhone, offer no vestiges of what he calls a true moraine; since although they contain occasional large erratic blocks, for the most part irregularly dispersed, all the other detritus is more or less water-worn, to great heights above their present bottoms. As Venetz and Charpentier have attached great importance to the original suggestion of an old peasant of the Upper Vallais, that a great former glacier alone could have carried the erratic blocks to the sides of the lower valley of the Rhone, so on the other hand the author, if he had had any doubt himself, would have relied on the practised eye of his intelligent Chamonix guide Auguste Balmat, who never recognized the remains

of "moraines" in that detritus of the larger valleys which has been theoretically referred to old glacier action.

In descending from the higher Alps into the main or trunk valleys, Sir Roderick found many examples of rocks rounded on that side which had been exposed to the passage of boulders and pebbles, with abrupt faces on the side removed from the agent of denudation, all of them reminding him forcibly of the *storm* and *lee* sides of the Swedish rocks over which similar water-worn materials have passed.

Seeing, then, that this coarse drift or water-worn detritus is distributed sometimes on the hard rocks and often on the remnants of the old valley alluvia, he believes that the whole of the phænomena can be explained by supposing that the Alps, Jura, and all the surrounding tracts have undergone great and unequal elevations since the period of the formation of the earliest glaciers—elevations which, dislodging vast portions of those bodies, floated away many huge blocks in ice rafts, down straits then occupied by water, and also hurled on vast turbid accumulations of boulders, sand and gravel. To these operations he attributes the purging of the Alpine valleys of the great mass of their ancient alluvia, and also the conversion of glacier moraines into shingle and boulders. He denies that the famous blocks of Monthey opposite Bex, can ever have been a portion of the left lateral moraine of a glacier which occupied the whole of the deep valley of the Rhine,—as Charpentier has endeavoured to show; and he contends that if such had been the case they would have been associated with numberless smaller and larger fragments of all the rocks which form the sides of the valley through which such glaciers must have passed. They are, however, exclusively composed of the granite of Mont Blanc; and must therefore, he thinks, have been transported by ice rafts,—which, having been forced with great violence through the gorge of St. Maurice, served to produce many of the striæ which are there so visible on the surface of the limestone*.

Fully admitting that the stones and sand of the moraines of modern glaciers scratch, groove, and polish rocks, Sir Roderick Murchison still adheres to the idea he has long entertained from surveys in Northern Europe†, that other agents more or less subaqueous, including icebergs and heavy masses of drift, have produced precisely similar results. He cites examples in the Alps, where perfectly water-worn or rounded gravel being removed, the subjacent rocks are found to be striated in the directions in which such gravel has been moved; and he quotes a case in the gorge of the Tamina,

* Mr. Charles Darwin, in a recent letter to the author, adheres to his old opinions on this point, derived from observations in America, and says, "I feel most entirely convinced that *floating ice* and *glaciers* produce effects so similar, that at present there is, in many cases, no means of distinguishing which formerly was the agent in scoring and polishing rocks. This difficulty of distinguishing the two actions struck me much in the *lower parts* of the Welsh valleys."

† See Silurian System, pp. 509 to 547; Russia in Europe and the Ural Mountains, vol. i. pp. 507 to 559; Presidential Discourses, Proc. Geol. Soc. Lond. vol. iii. p. 671, and vol. iv. p. 93; Journ. of Geol. Soc. Lond. vol. ii. p. 349; and Trans. R. Geol. Soc. Cornwall, vol. vi.

above the Baths of Pfeffers, where this ancient striation, undistinguishable from that caused by existing glaciers, has, by a very recent slide of a heavy mass of gravel from the upper slope of the same rock, been crossed by fresh scorings and striæ, transverse to those of former date, from which the markings made in the preceding year only differ in being less deeply engraved. He also adverts to the choking up of some valleys, particularly of the Vorder or Upper Rhine below Dissentis, by the fracture, *in situ*, of mountains of limestone, which constitute masses of enormous thickness, made up of innumerable small fragments, all of which have been heaped together since the dispersion of the erratic blocks; and he further indicates the effects of certain great slides or subsidences within the historic æra.

In considering the distribution of the erratic detritus of the Rhone, the author having denied that it can ever have been carried down the chief valley to the Lake of Geneva in a solid glacier, he still more insists on the incredibility of such a vast body of ice having issued from that one narrow valley, as to have spread out over all the low country of the cantons Vaud, Friburg, Berne and Soleure, and to have protruded its erratics to the slopes of the Jura, over a region of about 100 miles in breadth from north-east to south-west, as laid down in the map of Charpentier. He maintains, that in the low and undulating region between the Alps and the Jura, the small debris derived from the former has everywhere been water-worn, and that there is in no place which he saw anything resembling a true moraine; and he therefore believes, that the great granitic blocks of Mont Blanc were translated to the Jura by ice-floats, when the intermediate country was under water. He further appeals to the water-worn condition of all the detritus of the high plateaux around Munich, 1600 and 1700 feet above the sea, to show that a subaqueous condition of things must be assumed, for the whole of the northern flanks of the Alps, when the great erratic blocks were carried to their present positions.

Prof. Guyot of Neufchatel has endeavoured to show, that the detritus of the rocks of the right and left sides of the upper valley of the Rhone have also maintained their original relative positions in the great extra Alpine depression (Lake of Geneva), and that these relations are proofs, that nothing but a solid glacier could have arranged the blocks in such linear directions. But the author meets this objection by suggesting that there are notable examples to the contrary. He also refers to the great *trainées* of similar blocks which preserve linear directions in Sweden and the low countries south of the Baltic, to show that as this phænomenon was certainly there produced by powerful streams of water, so may the Alpine detritus have been arranged by similar agency. In alluding to the drainage of the Isère, he further points to the admission of Prof. Guyot, that nearly all its erratic detritus, both large and small, is rounded and has undergone great attrition; and he quotes a number of cases in which such boulders and gravel, derived from the central ridges of Mont Blanc, have been transported *across* tracts now consisting of lofty ridges of limestone with very deep intervening valleys; and therefore he infers that the whole configuration of these lands has been since much changed, in-

cluding the final excavations of the valleys and the translation of enormous masses of broken materials into the adjacent low countries of France.

In conclusion, it is suggested, that the dispersion of the far-travelled Alpine blocks is a very ancient phænomenon in reference to the historic æra, and must have been coeval with the spread of the northern or Scandinavian erratics, which it has been demonstrated was accomplished chiefly by floating ice, at a time when large portions of the Continent and of the British Isles were under the sea. Viewing it therefore as a subaqueous phænomenon, Sir Roderick is of opinion that the transport of the Alpine blocks to the Jura falls strictly within the dominion of the geologist who treats of far bygone events, and cannot be exclusively reasoned upon by the meteorologist, who invokes a long series of years of sunless and moist summers to account for the production of gigantic glaciers upon land under present terrestrial conditions. This last hypothesis is, it is shown, at variance even with the physical phænomena in and around the Alps, whilst it is in entire antagonism to the much grander and clearly established distribution of the erratics of the North during the glacial period. The effect in each case is commensurate with the cause. The Scandinavian chain, from whence the blocks of northern Europe radiated, is of many times larger area than the Alps, and hence its blocks have spread over a much greater space. All the chief difficulties of the problem vanish when it is admitted, that enormous changes of the level of the land in relation to the waters have taken place since the distribution of large erratics; the great northern glacial continent having subsided, and the bottom of the sea further south having been elevated into dry land, whilst the Alps and Jura, formerly at lower levels, have been considerably and irregularly raised.

JUNE 13, 1849.

The following communication was read:—

On the Valley of the ENGLISH CHANNEL.

By ROBERT A. C. AUSTEN, Esq., F.R.S., F.G.S.

THE valley of the English Channel presents two points of geological interest which may be considered as new—the one relating to the nature of its bed, as a guide to the conditions of origin of our older marine formations; the other to its age as an area of depression. For the former purpose the area may appear to be too limited; the extent of surface, however, from the Straits of Dover to the outward line of soundings, is more than equal to the whole of the South of England from the Land's End to the Wash, an area which comprises the whole series of English geological formations. Having had frequent opportunities of cruising about this Channel, I have been enabled, at one time or another, to visit nearly every portion of its shores on either side, and to examine its bed with the dredge and sounding-lead.

The English Channel occupies a valley bounded by two parallel systems of elevation. The line of 49° 58′, commencing from the east coast of France, near Dieppe, and which passes a little south of the Lizard Point, is as long a straight line as can be drawn within it. A physical area may have a general form and outline, which may not at all represent the direction of the forces by which it has been produced. The movements by which relief has been given to portions of the earth's crust are seldom continuously linear; the lines themselves, taken separately, are constantly seen to diminish in amount in opposite directions, and to be arranged *en échellon*. Such is the case along the South of England; the accidents of the strata run east and west; such is also the case in Lower Normandy and Brittany; this is their true direction as areas of elevation, of which the Channel is the intervening depression: a central line along this area would have a general direction from E.N.E. to W.S.W.; in this instance therefore the geological and geographical features are not parallel. Like instances may be traced wherever long lines of elevation have been produced. A central line from the Straits of Dover across the German and North Seas would equally mislead us there; the true physical features of that depression are the straight north and south line of coast along the departments of the Somme and the Pas de Calais, the rocky masses of the Varne and the Ridge rising with steep sides from deep water; the same line, if prolonged, will pass in front of the Goodwin Sand, along a trough having in places a depth of forty fathoms, and will define the coast of England from Orford Ness to Yarmouth. The direction of the troughs having thirty fathoms water are also parallel with this line.

A series of transverse sections from the coast of England to that of France, drawn north and south, will show that the Channel area is one of depression. In all such sections the sedimentary strata on either side have an inward dip. This position of all the secondary beds is familiar to most geologists, and hardly requires illustration. The east and west strike of the older strata to the west of the secondary formations is indicated on the map, and the like direction obtains throughout the palæozoic groups of Brittany and Lower Normandy. The lower valley of the Seine may probably be connected with the later disturbances of the Channel valley; the lines of deepest water are along its south side, and will be shown to correspond with its original greatest depression: it is a common character of linear undulations of the earth's crust, that they break into fractures or faults at their extremities. The general direction of the valley of the Seine from Havre to Rouen is due east and west. The remarkable cliffs which occur at places along this valley have been described by Sir C. Lyell; they can hardly have been produced by the present river, nor is there any accumulation of shingle along its course to account for its occupation by the sea. The features are difficult of explanation, but it suggested itself to me when I last saw them, that they were the result of a fault traversing a mass of elevated strata, by which portions had been let down; a depression of the strata on one side corresponding with the vertical wall of the cliff

on the other, according to what is to be observed in every valley of fracture. Whether this supposition respecting the valley of the Seine be correct or not, we at least meet with features on our own coast which make it probable. Thus, for instance, the vertical cliffs of the Watcombe fault have certainly been produced since the district existed in its present condition of dry land: the direction of this break is east and west. Again, Torbay, which is a portion of an east and west depression, has its recent age defined by the marine beds resting on the lines of elevation which bound it.

So much has been written respecting the quantity of matter carried down annually to the sea by rivers, that many have been led to regard it as the main source of submarine sediment: the English Channel is perhaps as good an instance as could be taken of the fallacy of such a supposition. The Seine is the only river of any magnitude which discharges into it. Now rivers carry forward matter in two ways—by holding it in suspension, and by drifting it along their beds. The quantity of suspended matter in the estuary portion of such a river as the Seine is occasionally considerable; but it is an inconsiderable portion of this only which finds its way out to sea at each ebb; whilst the sands which are subject to the drifting process accumulate in well-defined forms about its mouth. If we take the whole extent of the dry land drained by the rivers running into the English Channel, together with its mean elevation, we shall see that the whole of this mass, if removed down to the sea level, would be insufficient to fill up that depression. We may feel assured that the joint action of all the Channel rivers contributes but very little towards its accumulations. On comparing some old charts of the mouth of the Thames with the most recent ones, the principal feature in which they seemed to differ, was the present outward extension of the shoals and banks.

Sir H. De la Beche has treated of the action of the sea along its coast-line in full detail; it is this line which furnishes the great mass of materials we find strewed over its beds. To show that it is an adequate source, we have only to bear in mind, that in the instance of the area of the English Channel, if we follow its irregularities, we have an outline of not less than 1200 to 1300 miles, together with a great vertical range of tide. The removal of solid materials from the cliffs is not, however, so constant as some persons might imagine, not even on parts of the coast with yielding strata. There are very few places on our own side of the Channel, or on that of France, at which the sea at high-water regularly reaches the bases of the cliffs, and where it does so, from the hardness of the rocks, the rate of destruction is the slowest. As a general rule, it is only with high tides, concurrently with gales of wind setting on a given line of coast, that we see any considerable masses undermined and thrown down. If this be the case in such a sea as the Channel, where the power of the breakers is exhibited on so vast a scale, it teaches us to require enormous lapses of time for the production of sedimentary strata of the thickness of some of those for which the geologist has to account.

But though the sea for months together, and in places even for

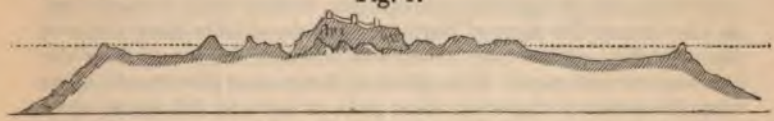
whole years, may not acquire any fresh spoil, yet there are very few hours when its waters are unemployed, in abrading and fashioning the materials already acquired. The zone of depth along which this process takes place is comparatively narrow; much of the gravel and shingle seems to travel up and down from the exposed beach to slight depths below; accumulation of sand may go on for a time, but a heavier sea soon disturbs this arrangement. The materials of long lines of beach may also be entirely swept away, and carried down into deeper water; in this way I have seen, at one time or another, nearly every portion of our south coast in the condition of bare rock without sand or shingle: the sea-bed has no permanent character over the first few fathoms of its depth. Bars, sand- and shingle-banks, belong to this zone, and these are likewise all subject to change of form and to removal, but they speedily collect again; and it is worthy of notice, as bearing on conditions to be observed at greater depths, that every part of this zone preserves its distinct character—the banks which form again after a sweeping of the marginal zone are always of the same description as were collected there before.

The materials composing shingle beaches clearly show that the ordinary action of the sea is at right angles to the coast-line, as they will I think invariably be found to have been derived from the contiguous cliffs. The line of flint shingle along the French coast, at the eastern end of the Channel, is exactly conterminous with the chalk cliffs, and like facts may be seen carried out in the minutest detail along our own western shores, at places where limestone, trap, or granitic rocks occur. In this case the action is simply that of the tide. With this, however, there is an occasional tendency for the shingle to travel onwards in a given direction. This movement has nothing whatever to do with the action of the tide; for as this in every channel makes in the offing before it does in-shore, its force, even if it was equal to such a process, is exerted at right angles, and not parallel with the coast. Along our own southern coasts the movement of the shingle is from west to east, and on the opposite coast of France it is the same. Wherever the direction of the wind coincides with the line of coast, an onward movement is imparted to the marginal line of water, and this moves the shingle along with it; thus the flint shingle from the chalk cliffs of the department of the Somme travels south, towards the mouth of the Seine, under the influence of north and north-east winds. The easterly movement of the shingle along our own coast may be easily observed; and in order to show that the assumed cause is a sufficient one, it is only necessary to establish the fact, that along the Channel there is prevalence of winds setting in the requisite direction. From the position of the Channel, any winds between north and south passing through the west, will act obliquely on the coast on one side or the other; and these up-channel winds are known greatly to preponderate over those which pass from north to south through the east. There is a peculiarity which has been observed with respect to the winds west of south, that they blow with most violence at the times of high tides, and particularly that they come in at the first of the

flood. We have taken the line from Dieppe westward as the one which indicates the line of the Channel: it appears that at this place, according to a register kept by M. de Bréauté, extending over twelve years, that the direction of the wind was 135 days between south and west, and 94 days between west and north, or 229 days out of the 365 during which the materials along some part or other of the Channel might have an eastward movement. There are no observations to guide us as to the rate at which the marginal line of shingle is made to travel forwards in this manner, but the distance at which it occurs from its point of origin is occasionally very great. On the Chesil beach may be collected pebbles of limestone, greenstone, trap, and old red sandstone, derived from the older rocks of South Devon.

Much of the irregularity of the present outline of the Channel, where it is independent of other causes, is due to the nature of the beds which occur along it. Passing over minor examples, good illustrations of this are to be seen in the deep bay between Berryhead and Portland, an interval which corresponds with that of certain yielding sands and marls; as also in the recess along the coast of Calvados.

Fig. 1.



Good illustrations of the process of cutting back along the marginal sea zone, and of the depth to which this action is carried in the case of hard compact beds, can be seen about the Channel Islands. Sections of some of these groups of rocks show that they rise off platforms, which have an uniform depth from the surface, and that from their edges there is a rapid fall to the general sea-bed below. The platform to the north of Ortach and Burhou comes nearly to the surface, so that the projecting points are uncovered: when the wind is fresh, the sea breaks violently on this platform; the fall is immediate into 18 fathoms water. Time being allowed, such a group as that of the Caskets (fig. 1) would ultimately disappear, and be reduced to a submarine shoal. Some of the actual shoals of these seas have probably at some former time existed as small groups of rocks;—that of the Pomier, two miles north-east of the Caskets, is apparently a good instance of a mass of rock reduced to its utmost with relation to the present sea-level. This shoal is a table-rock rising abruptly out of 170 feet water to within 36 feet of the surface, covered at top with patches of coarse sand and shingle, and, as usual, with a vast growth of sea-weed. Viewed in this way, the Channel Islands group, taken collectively, will present instances of masses in every stage of abrasion; and judging from the soundings round the several shoals, rocks, and islands, the depths to which such masses may be reduced will range down to between 40 and 50 feet at the very utmost.

This process, by which masses of solid materials can be planed off parallel with the sea-level, is due to the action of wind or surface

waves, inasmuch as in calm weather, when I have had opportunities of passing over some of these platforms, I have felt convinced that the only other agent, namely the tidal streams, had not sufficient velocity to exercise any mechanical power whatever.

With the present tendencies of geological speculations, it is of some interest to ascertain, if possible, the depths at which the sea-bed is liable to disturbance: on the determination depends the knowledge we may some day acquire of the conditions of accumulation, which the older stratified deposits exhibit.

Whenever a stream of water flows over a rocky or uneven bed, the interruption which the lower stratum experiences is indicated by a wave-disturbance at the surface: of this every running stream is a ready illustration. In parts of our seas, surfaces of broken water, known as races and overfalls, are constantly met with, and may even be observed from the land. The race of Portland occurs over a ledge of rock which runs out from the south extremity of the Bill; the east and west sides of this ledge are steep: the case of the St. Alban's race is precisely similar. The surface-disturbance at these places is to be observed in the calmest weather, and in drifting over them at such times, the passage from smooth into broken water is immediate. In like manner the race of Barfleur, more formidable than either of the preceding, occurs over a ledge of rocks, running out from the headland of that name. As in all cases, the greatest disturbance, apart from the action of the wind, takes place at new and full moon, when the tide-stream flows with a velocity of from eight to nine miles an hour; showing that the races are due to the arrest of the tidal stream by these ledges. The Boulogne fishermen sink their nets athwart the deeps at the east end of the Channel; should the weather become too rough to allow them to get them in, they are sure to recover them on the coast between Cape Gris Nez and Calais, whither the flood tide drifts them in. These and many like cases to be collected along the coast show that the tidal movement extends to the whole depth of water. These cases are to be observed along the marginal zone, and some persons have drawn a distinction between the movement of the tide in deep as compared with shallow water. A broken or rippled surface is met with at certain places in the open part of the Channel, as along the entrance from the Atlantic: these appearances are in every instance connected with uneven ground below. The ripplings over Jones's Bank are very considerable; the shoalest part of this bank has 40 fathoms, with a surrounding sea-bed at 70. A like surface disturbance is constant along the edge of the Nymph Bank, which has a minimum depth of 45 fathoms. The Little Sole Bank has like indications even in the calmest weather: over the summits of this group there is a depth of 60 fathoms, with 100 fathoms at short distances around. In all these instances the place and extent of the ripplings depend on the direction and strength of the tide: the slopes of all these banks are steep; the process is the same as with the shallower ledges, and shows, according to what theory requires, that the tidal stream movement extends to the whole depth of the Channel.

In the earliest accounts we have of the Channel and its dangers, we

find notices of "races" as occurring at the very spots at which we now meet with them; tending to show, that whereas the action of breakers along the coast-line has, within comparatively short times, produced great changes, by the removal of thick masses of strata, yet that no corresponding abrasion has been effected over these ledges under depths of not more than 17 fathoms.

The difference of velocity between the upper and lower strata of water put in motion by the tidal stream, as in every current, is less over the bed than at the surface; but the surface velocity, even in parts of the Channel where it is greatest, cannot be estimated at more than from five to six miles an hour, so that its movement over the ground or as a mechanical agent is very trifling.

The two actions, first, that of wind-waves when they break in shallow water; and, secondly, that of the tidal stream, are alone engaged in fashioning and arranging the materials of the sea-bed *. The principal action of the wind-waves, as exercised on the land, is confined to a zone extending from one range of the tide to the other. In a zone below this, a certain amount of shifting, and consequent abrasion of the materials, may take place; the breadth of this zone will depend on the nature of the coast, whether shelving or otherwise; for with the deepening of the bed beyond the line of wave-undulation this direct littoral action ceases. It would be difficult to lay down the precise zone of depth along which the action of wind-waves may be considered to cease; but as in high waves of this order, at a depth equal to one-third of a wave-length, the range of oscillation of the particles is only one-thirtieth of that of the particles on the surface, the depth to which water can be affected in any part of the Channel cannot be very great. Where the action of the wind-waves ceases, the permanent influence of the tide-stream begins; and as this extends to every depth and portion of the Channel, it has for its limits, as an agent of accumulation, only the length of time during which particles of matter may remain in suspension: in short, in every sea the power of abrasion is confined to a marginal zone, and that of dispersion, though with a wider range, extends only to the minuter particles of matter.

I am aware that a very different view of the movement of the water of the Channel has recently been given, and that in support of it the areas of discoloured water over certain banks at great depths, as well

* It is only proper to state, that M. Emey, who has treated the subject of the movement of the waters of the sea in great detail, so far as bars, sand- and shingle-banks, and even erratic blocks are concerned, attributes them to the action of what he terms his ground wave (*flot de fond*); that is, to the motion of the water near the bottom towards the shore. (Mouvement des Ondes, p. 51.) M. Emey adduces, as practical tests of his theory, first, that when bathing in the sea, at a short distance from the shore, and with the body upright, we are lifted up by the surface-undulation, whilst at the same time the horizontal passage of the ground wave to the beach is felt by the legs. Again, if two pieces of cork, one weighted so as just to sink to the bottom, be thrown into the sea, the floating piece will keep its distance from the shore, and only follow the surface-undulation, whilst the weighted one will be rolled along the bed, and thrown up on the beach.

as rippled surfaces, have been used as proofs that to such depths the sea-bed may be disturbed by gales of wind. It may be asked, on the other hand, how is it, if the oscillation of wind-waves at certain places can reach down to the bottom so as to disturb the bed, they do not do so equally over those wide areas where the sea has an uniform depth of that amount? Against this too may be adduced the direct and important testimony of those persons who have worked from the diving-apparatus, that with a fresh breeze and considerable surface-movement no disturbance was ever to be experienced below.

Discoloration is at all times to be noticed over the banks in question, even when the sea is perfectly quiescent, as far as wind-waves are concerned: we know from soundings that these places are within the range of fine sedimentary deposits; and with respect to matter falling through water slowly, we know, that at the distance of these banks from any land, it will be principally in the lower strata of water that the suspended matter will occur. The tidal current which has carried a column of water of 500 feet over a considerable space, on meeting one of these banks, is suddenly reduced to 300 feet. The effect of this is to produce that peculiar form of disturbance which resembles a boiling-up and flowing-off of the surface, and which is so characteristic of shoal disturbance in perfectly calm weather. By this process lower strata of water are forced up, and bring with them the finer particles which had reached those depths. The change in the colour of the water at these places is however very slight, being from blue to a pale disturbed green, and the quantity of suspended solid matter by which it is produced is exceedingly small.

§ 1. *Distribution of Materials and Map of the Channel.*

As the coast-line is the only source whence the materials which compose the sea-bed are derived, and as the movement of the water, at inconsiderable depths even in advance of this line, is totally insufficient to produce the forms and conditions of the materials which occur there—the same also with respect to all subsequent outward zones of depth—the mass forming the sea-bed at every place must have travelled outwards. The coarser materials of several areas can be identified with the rocks on the coast from which they have been derived: thus granite and tin-stone shingle occur round the Land's End and Scilly Islands, whilst the syenites and allied rocks of the Channel Islands group take a wide range on that side of the Channel. In addition to such instances as these, we have also the evidence from the shell-sand beds, which constitute such extensive areas in our Channel, and apparently in all seas; few if any of the shells whose fragments are so abundant over these areas belong to them, or have lived there: sharp sands, and such as can drift, are especially poor in submarine life, nor do we meet with any weed. The great proportion of these shelly materials has come from a contiguous higher zone; but mixed with these, and in considerable abundance, are the pounded fragments of the commonest littoral species; thus the *Haliotis tuberculata*, one of the peculiarities of the Brittany and Channel

Island coast fauna, and which lives just below ordinary low-water, has its fragments carried out fifty miles from the nearest coast; with it, and abundantly, is *Patella vulgata*.

The general character of the sea-bed of the Channel is, that its component materials become finer as the distance from the coast-line and the depth of water increase. This relation of sea-bed to depth was long since noticed. In Lord Anson's 'Voyage' (1740–47) he states that he has tried soundings more frequently, and in greater depths, and with more attention than had been done before, and from the remarks occasionally made on their value, and the occasions on which they were taken, he seems to have relied on them when navigating unknown seas, as a sure indication of his distance from some land. His observations give

80—60 fathoms fine sands, mud and ooze,
60—40 ,, sands with broken shells,
40—12 ,, coarse sands, pebbles and small stones,

and appear generally to have been taken along lines of open coast.

These numbers are not here produced as the rule or scale of depths regulating the distribution of materials by the sea. But if we take lines of soundings seaward, we shall invariably find a progressive change as we advance from deep water and open sea, from mud to mud with sand, next sands which increase in coarseness; small subangular pebbles; and across beds of water-worn materials, described as of the sizes of peas, coffee-berries, beans, almonds, pigeons' eggs, &c., till we finally reach the marginal banks of gravel and shingle; so that the term soundings is well made to designate both the depth of water and the nature of the sea-bed—the condition of the one being the result of the action of the other. The bearing of this relation of sea-bed to depth, to what forms the greater part of the detail of pure geology, is obvious: the vast series of sedimentary deposits, nearly the whole of our areas of dry land, are the aggregates of the soundings of ancient seas, presented to us in their progress through long periods of time*.

Among the more interesting points connected with the subject of the older sedimentary deposits, are those known in descriptive geology as—§ 1. Mineral character; § 2. Stratification; and § 3. Sequence of deposits.

§ 1. Mineral character is simply the result of the process of distribution by a body of water in constant motion—an operation, the precise counterpart of what is employed in various economical processes whereby mixed materials are separated, arranged and carried forward according to size and specific gravity. The divisions on the Map of

* I had long since entertained the notion that geological speculations might be greatly assisted by a careful study of any given area of sea-bed (Geol. Trans. vi. p. 454), and the notes from which this paper has been drawn up date back many years; but I am ashamed to confess that at the time it was communicated to the Society I had not read Mr. Darwin's Observations on South America: the whole work is a rich store of facts and correct inferences, and as bearing on the observations contained in this part of my paper, I would refer to Mr. Darwin's first three chapters, and more especially to the first.—*December* 1849.

the bed of the Channel are as distinct as any which we establish on geological maps between portions of formations which differ mineralogically,—as between the lias clays and the oolitic sands which surmount them. The mud beds forming in ninety fathom water in the central trough of the Channel, are geological marls and clays; the only difference they present from one place to another being dependent on the source whence the constituent particles have been derived. On the English and Irish side of this deep area, the sea-bed is a black impalpable mud, the shells of Dentalium apparently very abundant, an accumulation such as in former seas has produced beds of lias, gault, or London clay. On the French side of the basin are white and yellow marly beds of like tenacity, and at the same depths, being apparently the finer particles derived from the feldspathic rocks, which the rough seas of that angle of the Channel are unceasingly abrading. Under the deeper water of this central area we obtain soundings of a mixed mud and finest sand, the exact counterparts of beds we are familiar with in connexion with the argillaceous portions of every formation, and which here seem to serve as a connecting group between areas of totally distinct mineralogical characters.

An area which would contrast strongly with that of mud and ooze, could the bed of the Channel be raised into dry land, would be that of the clean siliceous sands, which would present a continuous extent of surface equal to two-thirds of the South of England. The formations with which such areas as these suggest comparisons, are that of Bagshot, or the lower greensands, considered in horizontal, not vertical extent.

Higher up the Channel are accumulations of sand with coarse subangular and rounded shingle, and largely mixed with this mass are the dead shells of the larger mollusca. There exist then, even in our own Channel, large areas over which materials of distinct mineralogical character are being separately accumulated; and in this respect there must have been a complete identity in the operations of former times.

Upon this point a difficulty has been felt by many geologists, who being well-aware of the additions constantly being made to the materials of the sea-bed, have thought it strange that soundings should present such remarkable constancy as to depth. M. Brongniart and others have gone so far, on this ground alone, as to draw a line between the operations of present as compared with former seas, and to deny to the present seas the power of producing deposits which can in any way be compared with those of geological periods. "Wherever," he says, "we have been able to ascertain the nature of the sea-bed of any of the actual seas at distant times, we find it to have been the same as it is now." Such is no doubt the case, though the illustrations cited by M. Brongniart are not altogether unexceptionable. It may safely be admitted that in our own seas there is no variation in the depth or quality of the sea-bed. The soundings now obtained agree with those laid down by Captain White; and the French surveyors of their western coasts confirm the same fact, in the direct observations taken for the verification of their charts. The places are very few where fishermen and pilots seem to think that any vertical

accumulation or depression is taking place—any at least of a permanent character; and the reason of it is, that accumulation does not take place in this direction, but according to a process of outward distribution already alluded to. The materials of the sea-bed are in equilibrium with the moving power of the water at every place; the sediment of the ninety fathoms' depths could not remain between the mainland and Alderney for a single tide. Should any extraordinary action of the sea, such as that of a continued gale and high tides, produce along the submarginal zone a deeper disturbance than usual, the common effect is, that an accumulation of sea-bed is brought up from such deeper zone and thrown down on a shallower one: such a disturbance is not unusual, but the effect is not permanent; such materials being within the ordinary moving power of the sea in their new place, are soon carried away*. In the course of last summer I received some curious information respecting the formation of such temporary banks, from men engaged in the oyster fisheries on the French coasts. It seems that with a continued gale from the west, large areas of their dredging-grounds become at times completely covered up by beds of fine marly sand, such as occurs in the offing, and which becomes so compact and hard, that the dredge and sounding-lead make no impression on it: with the return of the sea to its usual condition, a few tides suffice to remove these accumulations.

§ 2. The large areas of uniform sea-bed, wherever there are long lines of uniform depth, are the obvious results of the laws which we have seen determine the quality and distribution of submarine materials. The termination of deposits of a well-defined character, such as the shell-gravel beds or those of clean sand, is often by slopes more or less steep; the two conditions taken together point clearly to the mode of accumulation. If we take the great sand plain, the particles brought down are drifted on over the horizontal surface, till they reach the edge of that quality of sea-bed or soundings; they then fall over the slope, and are beyond the reach of the combined action which has moved them along: it is only therefore in advance of each area of definite character that the materials belonging to it are ultimately deposited. It is this process which has produced that diagonal arrangement to be observed in so many deposits from the crag to old red sandstone. The red crag shows us instances of the coarse-ground sea-zone, the coralline crag of the region of shell-sand. A modification of this arrangement is presented by these two groups; in the red crag we meet with a structure which may be called torrential, by an application of M. Necker's term; with this we meet with constant instances of the partial removal of the upper portions of subordinate beds, subsequent to their accumulation: with the coral-

* The Schöle bank rises out of twenty to twenty-five fathoms water. In 1824, Captain M. White describes it as having steep sides and covered with only seven and a half feet of water. He surveyed it again in 1831, and found it much increased in size, with regular soundings about it. In 1833 the French surveyors found it much in the condition in which Captain White first described it. Such an instance as this indicates only rapid accumulation for a few years, followed by as rapid removal. There are many cases of like character, but they all belong to the submarginal zone at most, and to this very rocky part of the Channel sea-bed.

line crag there are seldom continuous beds of great extent, but a simple arrangement of diagonal laminæ. Portions of the lower greensand present us with instances where the component strata are carried on for great distances, with their upper and lower planes strictly parallel, and with cross structure throughout in the same direction: in these cases the angle of laminæ is uniformly higher than in the more confused and shorter bedding. The angle of rest for drifted sand will be high in proportion to the stillness of the water into which the sand-bed is extending itself; so that in these several well-known characters of deposits we seem to have a guide as to the condition of depth and directions of moving power over these old sea-beds.

In the torrential structure of river deposits the direction of the bedding is with the stream. In marine beds we constantly meet with it, as in the pleistocene drift and crag deposits, setting in opposite directions in consecutive beds, as contradistinguished from those setting constantly in a given direction. In the first case the materials are mostly mixed and coarse—laminated sands, between horizontal gravel beds; in the latter the materials are finer, and indicate the undisturbed process of constant outward accumulation. In the confused stratification alluded to, and in the thin layer of sand which is so constantly interposed between masses with opposite diagonal bedding, we have an arrangement which may be due to tidal influence. If we take a portion of the east end of the Channel, and where the tidal movement of the water is well known, we find that the flood at the syzygies runs $4^h\ 40'$, at the ebb $6^h\ 50'$; that the minimum velocity, which depends on the height of the tide, is at most half of the maximum velocity, or that with high tides the flood is more rapid than the ebb. Making allowance for these different forces and directions, the confused arrangement to be observed in these deposits becomes intelligible.

In the deeper sea sand beds, which travel outwards by additions in front, the formation of a single stratum may be continued until the effect of its accumulation is such on the body of water entering such sea as to admit of a new bed being formed above it; so that the interval of time between one stratum and another in this zone may be very great. The dimensions of strata of this kind are greater than those presenting other arrangements. Diagonal beds of great thickness may be noticed in the crag deposits, and I have seen them upwards of twenty feet thick in the lower greensand, a thickness which would correspond with a sudden increase in soundings of from three to four fathoms.

A very common form of arrangement is where the lines of deposition are parallel with those of bedding; in this case we seem to have no guide as to zone of depth. We meet with it in the so-called raised beaches, which are marginal sea-beds, ranging down to 10–15 fathoms. The stratification of the beds at Braunton is most distinct and regular. This mass is the shallow water accumulation of a sheltered bay; but we may trace the same arrangement in beds which were evidently deep and wide sea deposits, such as those of the white chalk, or where like masses have been altered into crystalline limestones.

But even here, in proportion as one part of the formation affords indications of greater depth than the rest, as between the chalk marl and upper chalk, so stratification becomes less distinctly marked: the deep sea mud-beds, such as the old slate rocks in their original condition, the London and other great clay groups, are not stratified, but only laminated. Lines of stratification are obviously due to an interference from time to time in the process of horizontal deposition, but as to the cause in this particular case I am unable to offer any conjecture, nor can I meet with one.

In a sea where accumulation goes on by an outward distribution of materials, there will be an obvious tendency to form banks and terraces. The termination of the sands over the mud-bottoms are of this character, and such are also the accumulations of a higher zone which surround the deep pits between the coasts of France and those of the south-west of England.

In order to realize the geological bearings of such processes as we have here considered, we have only to imagine a long valley formed by subsidence or otherwise, to be so placed that the waters of an adjacent sea should flow in and occupy it to the depth of 100 fathoms. The nature of its action would be as follows: The products of wave destruction along the coast-line would be carried outwards and arranged in zones according to states of comminution and specific gravities; simultaneous accumulation of all these various conditions of detritus would take place, and if followed from the coast-line outwards would present a gradual change from one mineral character to another. By lapse of time and process of accumulation, the bed of such an area would be raised, the depth of water diminished; sands would then be carried out where silt and ooze had been deposited at first, and beds of coarse materials would occupy the zones of finer sands. The accumulations from either side might thus be brought up, till a large portion of the area would have the kind of sea-bed known as coarse-ground. When the higher portions of such channel no longer offered any places for the finer sediment, it would travel outwards, or towards the opening and lower portion of such depression; and the whole of such an area would bear the same relation to the wider ocean with which it communicated, that its own river estuaries bore to itself. Such is the actual relation of the English Channel to the Atlantic Ocean: it is the estuary of the rivers of a portion of Western Europe, in which are repeated on a wider scale all the phænomena of tidal action which minor estuaries exhibit.

In the case here imagined, we have assumed a given area or valley of depression, modified afterwards by the process of accumulation alone; the whole of the process would be conducted along a very narrow zone of breadth compared with the extent of the sea, whenever the sea was an open one, and for all geological purposes such lines of section will perhaps be safer guides than those taken in close seas. In our own Channel, as we shall see, the area of sedimentary deposits is bounded on the west by the barrier which separates it from the great valley of the Atlantic: the distance of the deep sea mud from Cape Clear south is about the same as that of the same deposit from the Scilly Isles,

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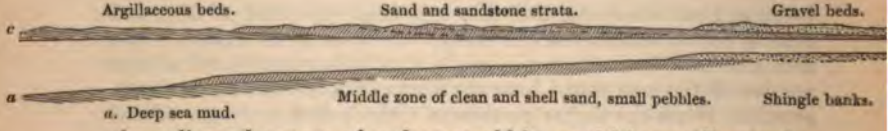
and agrees with the distances given below, the results of a number of lines of soundings derived from charts. The inference we must derive from this is, that extended lines of deposits, having an uniform mineral character, must have had at their periods of deposition a certain parallelism with the coast-lines of their seas.

§ 3. The necessary and obvious result of a process of accumulation where the quality of the sea-bed is dependent on depth and distance, and where the progress of the several zones of materials is outwards, will be, that in process of time each distinct zone of mineral matter will overlap the one immediately in advance of it. A deep sea channel thus filled up would present, in the long vertical sections through its bed (which is the manner in which we look at ancient sea-beds), a gradual change in mineral character; the tenacious mud would pass into fine silt and ooze—the original deep water beds; after a certain amount of accumulation, these would be surmounted by the sands of the next zone of depth, a progressive increase in the coarseness of this arenaceous series would be observable; lastly, the coarse ground zone would be found running out and resting on that of clean sand: throughout the series, taken as a whole, there would be a regular order of superposition. If we imagine a sea-bed, *a b*, thus accumulated, to be subsequently raised to an uniform level, without any reference to the former depths of deposition, just as the deposits of the secondary and tertiary periods mostly are at present, and be made to exhibit a section at right angles to its coast-line, we should have, first, such a succession as represented fig. 2; and which if described in

Fig. 2.



the ordinary language of geology would be—a thick ascending series, commencing with clays and marls, or pure limestones, according to the preponderance of the remains of animal life (Zoophytes, Mollusks) over that of the mineral masses on the coast-line, passing up into and succeeded by a vast accumulation of sand, and finally surmounted by coarse beds of gravel and shingle: concurrently with this mineral change, there would be another as great in the suites of animal remains, if we confined ourselves to such as should indicate that they had lived at the places where they might occur.

With respect to the finer and more distant sedimentary beds, the change upwards in mineral character would be progressive; whilst in other cases, and nearer the coast-line, where an accumulation of sand or gravel might have travelled out with a diagonal arrangement over a previously formed sea-bed, the line of separation might be very defined, or as we should say geologically, the mineral character would change suddenly. All these appearances might be presented, and yet not warrant the supposition of any violent physical change; the sea-bed of this and of every past period must be considered as a syn-

chronous series, of which every portion has been derived from one common source—the coast-line. At particular places, in sections taken through them, masses of one set of materials would be found resting on another, as sands upon marls, and gravels upon sands; and we might find these sands dipping away as a mass from the one, and passing at the distance of a few miles beneath the other, as in section fig. 2; yet the only inference will be that the marl beds, which, in a vertical line, are beneath a mass of sand, are before them in respect of time; not, as we now imagine, that any one group or portion of a series had priority as a whole.

The application of these several conditions of accumulation to the deposits which form our tertiary and secondary series of formation, forms the second part of this communication: and the only point I would now notice, connected with the bed of the Channel, is the remarkable irregularity it presents at its western boundary, but which it would have been premature to have noticed in the early observations on the Channel as a physical area.

The law of progressive change in the character of sea-bed requires that the most remote deposits of the Channel should be the finest, and that no coarse materials should occur at any considerable distance from the coast: this law holds good for a given extent round all the shores of the Channel, but beyond the area of mud and ooze, fine and coarse sands, shingle and bare rock are again met with. It will be seen by the map that the Channel bed slopes gradually west through 8° or 9° of longitude, but that instead of running on with such inclination into the valley of the Atlantic, after having attained a depth of 90 and 100 fathoms, it rises again to within 50 and 60 fathoms of the surface: it is on the sides of this rise that the coarse beds occur. The moving power of the sea at 60 fathoms (the highest level of these rises) is limited to fine sand; but the whole of these groups, whether the Sole Banks or Jones's, are separated from the zones of coarse materials depending on the coast-line, by a broad intervening area of the finest quality of sea-bed. We are precluded from supposing that the lines of coarse materials can have travelled over the mud zones, as their upper surface is soft and incoherent, into which the sounding-lead sinks some distance before the mass is tenacious enough to stop it, and in which the dredge buries: if therefore marginal or submarginal zone materials are found in places beyond well-defined areas of the low moving power of water, they become a clear indication that since their accumulation a great change in the position of such place, as to depth of water and distance from coast-line, has taken place.

If we take the contour-lines of the Channel valley as they are given on the accompanying map, beginning from the coast, it is very evident that they conform to the features of that coast-line, particularly where it is due to physical structure; a larger scale, and an intermediate 5-fathom line would show this in a very remarkable manner, in the case of one or two valleys of fracture: the features derived from the direction of given masses are continued through the submerged portion of the valley, and are merely modified by the quantity of modern sea-bed accumulated over them. Thus the Channel Islands are the west

extensions of the masses of crystalline rocks of the Cotentin, which occur in the cliffs of its coast at places due east; the submarine run of these masses is indicated by the rocks across the intervening sea: it is the unyielding granite ridge, which connects the granite of Alderney with that of Cape la Hague, that causes the race at that place, and so throughout the whole of that group (*vide* Map). On our side of the Channel the mineral character of the crystalline rocks is different from that of the Cotentin and Brittany; the granite of Scilly belongs to the west of England group, and due west again is Jones's Bank, a nucleus of solid rock invested with granite sand and shingle. This conformity of contour-lines to the coast becomes weaker as we proceed seawards, and at the distance of the 50–70-fathom line of soundings has only a general agreement with it; the deep sea-beds are spread out over this area: beyond these the configuration of the sea-bed begins to put on a new direction, and in its extension west we find that this depends on the form of the mass, which rises between 48° and 49° north lat. and 8·30° to 10° west long.

The places along the opening into the Channel at which we meet with shingle and gravel are very numerous; some of these are indicated on the map, but the scale is too small for the admission of all; but with respect to them all, we must suppose, as in the case of the Little Sole Bank, that they are the indications of a marginal zone or coast-line.

It may be objected to this, that these distant sand, gravel and shingle beds may belong to any age, and not in any way be connected with the present seas. In tracing the remains of marine animals seawards, we may observe a like gradual comminution with that noticed with respect to mineral materials, long after the forms of shells have ceased to be recognizable. The sea-bed, particularly on the French side of the Channel, is mainly composed of shell-sand, or sand in which few particles of anything but such as show shell-structure occur. Areas of this character are laid down by the French surveyors, and occur in the interval between the Land's End of France, or Ushant, and the Little Sole Bank; yet on the sides of this bank, and more particularly on its western slopes, large, perfect, though decayed shells again occur, and what is more remarkable, *Patella vulgata*, *Turbo littoreus*, &c. Taking the two phænomena together, the occurrence of littoral shells and of marginal shingle, we may safely infer that we have at this place the indication of a coast-line of no very distant geological period, buried under a great depth of water, and removed to a great distance from the nearest present coast-line.

The duration of time, estimated in the ordinary measure, during which the sea must have worked at its present level, must have been very great, from the extent and uniformity which its zones of deposit have attained with relation to that level; and it may be argued, that if such be the case, these coarser beds and littoral shells would not now lie exposed on the sea-bed, but would long since have been covered up by the accumulations of fine deep-sea sedimentary matter.

struction the Little Sole Bank offers to the flow of the tidal into the Channel—the surface-disturbance resulting from it,

which is always to be observed over the whole of the area—the suspended matter which the water here indicates—alike favour the supposition that the minute particles of matter which could alone find their way to such a distance, could not accumulate at such a place.

If on such evidence we assume that the whole of the Channel valley had at some former period a higher level than at present, many other anomalies become intelligible. The banks of the Channel, such as Jones's, have tabular summits, often of rock, whilst the sides are steep, and composed of coarse materials; they are just such masses as some of the groups of rocks (such as have been already noticed in the vicinity of the Channel Islands, and which have been cut down by the prolonged action of the sea at a given level) would be if let down into fifty fathom water. The summits of all the Channel banks keep nearly the same depth, and would seem to point to some former higher and common level, for their distance from the present surface is such that the sea cannot possibly affect them mechanically.

In the very coarse beds which form the floor or lowest levels of the Deeps in the upper part of the Channel, from the meridian of Cape la Hague eastward, and which have a depth of forty and fifty fathoms, we also seem to have the highest marginal zone of some former period, over which the drifting beds of the actual period are spreading; and on the other hand, such masses as Jones's bank are to be considered as protruding portions of an older sea-bed isolated amidst the ooze deposits of the present sea.

The data are as yet too few to enable us to determine whether indications of more than one former permanent level can be detected in the characters of these portions of the Channel bed; but there is enough to warrant the conclusion, that at certain places former depths must have been different, and apparently less than they are at present, and that one such marginal level existed about the line of fifty to sixty fathoms.

There is yet a point to be noticed connected with the physical history of the Channel valley, and that is the nature of the rise which takes place at its western extremity, and which serves as its boundary with respect to the Atlantic depression. The Little Sole Bank has depths on its eastern side of ninety fathoms; but this rise is very trifling compared with that which its western slopes present. I have attempted a representation of the outline of this portion of the Channel sea-bed, by the aid of the soundings which have been taken by the French and English surveyors; and in explanation of it, it may perhaps serve to give a better notion of the extent of inequality of surface here indicated, if I borrow an illustration from the physical features of a well-known district, than to attempt to represent it by sections*. Within a distance from the summits of the Little Sole Bank, not so great as from the top of Snowdon to the sea, soundings have been obtained of 529 fathoms; in other words, the Sole Bank rises from that level to a greater height, and more rapidly, than does

* Lengthened sections having an approach to a true scale accompanied the paper when read; these cannot be reduced, and to alter the scale of distances and depths would be to do away with their use.

the mass of Snowdon from the sea-level of the Caernarvon coast by the Menai Straits.

The character of the greater part of the Channel area, if laid bare, would be that of extensive plains of sand, surrounded by great zones of gravel and shingle, and presenting much such an admixture and arrangement of materials as we may observe at present over the Bagshot district of deposits; whilst along the opening of the Channel there is an obvious configuration of hill and valley, and an amount of inequality equal to that of the most mountainous part of Wales.

From the summit-levels of the Little Sole Bank to the 200-fathom line of soundings on the west, the slopes, though steep in places, are regular. If we deduct the fifty fathoms of water, the remainder will give 900 feet for the elevation of this ridge above the 200-fathom level; or a range of hills having just the same uniform tabular elevation above such line that the Haldon and Blackdown ranges have above the present sea; it is about the lower levels of this group that the coarse materials already noticed seem to occur.

Beyond the 200-fathom line the outline is irregular, and sinks rapidly to very great depths. This remarkable fact occurs not only at one particular spot, but is continued northwards, and in the contrary direction has been traced by Captain Vanhello from Cape Finisterre to the parallel of the Lizard. The investigation of this line seems to have been the special service on which he was employed in 1828 and 1829. He states that immediately beyond the 200-fathom line they often failed to obtain soundings by running out as much as 400 fathoms; and also that the ridge of the Little Sole is placed on the east edge of that 200-fathom line. Of the true nature of such a sudden line of depression we can at present only form conjectures: it may represent lines of old escarpments; or should lines of sea-cliff have gone down rapidly into deep water, where no mechanical action could modify them, such features would be preserved: lines of faults and upheaval would also present such unequal soundings; but the outline is too irregular to represent the termination of the sedimentary mass of the present seas; besides which, we have constant indications of a surface of bare rock.

Sir H. De la Beche has represented the course of the 100-fathom line round the British islands*, with which that of 200 fathoms has a very close conformity, and he remarks on the agreement which this line presents with that of the strike of the older ranges of this country: such is undoubtedly the case with respect to a portion of this line; but if it be suggested by this, that the date of this submerged line be the same as that of M. E. de Beaumont's 'System of the North of England,' it must be remembered that this 200-fathom line, if viewed along its entire length, presents no such parallelism,—that it is continued along the coasts of countries whose ranges present

* Theoretical Researches, p. 190. In closing these observations on the condition of the bed of the Channel, I gladly acknowledge my obligations to this work; to it, and Sir C. Lyell's 'Principles,' I must trace the idea I have attempted to work out.

no accordance with that of the north of England,—and that it crosses at right angles, and cuts off ranges, which not only have been raised, but were deposited long after the 'System of the North of England' rise took place.

§ 2. *Age of the Channel Valley.*

The valley of the Channel being due to depression and not to excavation, the geological period of such depression is another obvious point of interest connected with it.

From the parallelism of the valley of the Channel with certain lines of elevation along the South of England, Sir Charles Lyell has suggested that the movement from which this configuration resulted might be referred to some portion of the eocene period: but with such an abrupt termination as the Bagshot series presents, and with the occurrence of the lower portions of the eocene deposits up to the very edge of the chalk escarpment of the Wealden denudation, we must suppose, as we do with respect to the secondary beds of the same district, that the whole of the eocene group, as it exists in the South-east of England, was originally carried continuously over the Wealden; and that the phænomena of denudation of this district are entirely referable to some post-eocene date: geological features, or rather physical ones, may present parallelism, but these will be found to have very little connexion with the question of geological age.

The only way by which to test the relative levels which portions of a country may have had at any distant time, is by the beds which occur over them. If of two areas, one presents a surface of eocene strata, and the other, like eocene deposits, surmounted by distinct and younger beds, of the existence of which the other area offers no indications whatever, we rightly infer that these two areas had in the interval assumed different relative levels. Such is the difference between the two valleys of the English and German Channel—the crag deposits occupy both the English and Belgian sides of the German, whilst they are altogether wanting in the English Channel valley. Between the uppermost freshwater deposits of Hampshire and the Isle of Wight, we have no indication whatever of marine beds containing intermediate forms between those of the eocene and present seas.

Marine beds containing existing species occur at intervals along the coast-line of the English Channel: they were never probably continuous, and all belong to the marginal zone. The movement of the materials of this zone, in the present state of the Channel, has been noticed in the former part of this paper, as taking place in a direction from west to east.

In a description I gave of raised beaches at the entrance into Torbay and at Slapton, I stated that chalk-flints, and other materials from rocks to the eastward, entered into their composition, and that these materials were not to be found in any of the beaches in the vicinity at present. I re-examined these beds in the course of last summer, and found the proportion of chalk-flint, in subangular fragments, far greater than from recollection I had supposed it to be. It must not be understood from this that chalk-flint pebbles are not to

be found with the shingle on any West of England beach at the present day; a great mass of flint shingle occupies the middle portion of the Channel far beyond the range of the chalk strata on the coast: and these very raised beds must have continually supplied a portion: the difference consists in the amount of wear, and relative proportion—on the present beaches they are exceedingly scarce, and only in the condition of rounded shingle: the like holds good with respect to the raised marine beds with chalk-flints at every other place.

Sir H. De la Beche has noticed the presence of chalk-flints in the "raised beaches" he has described on the coast of Cornwall, and adds, "The occurrence of these flints, as at Coverach Cove and at other places in the Lizard district, while they are not found inland in the adjoining country, is not easy of explanation*." On the other side of the Channel a like mixture of chalk-flints with other materials is described by Sir W. Trevelyan in the raised marine beds about the Channel Islands†. Such facts clearly indicate that the marginal movement of the materials, during the period of accumulation of these raised deposits, was from east to west along either side of the Channel, or the reverse of what takes place at present.

These accumulations have hitherto been noticed as proofs of recent changes; but in my communication on the subject in 1834, I noticed the poverty of the marine fauna of the period to which they belonged, and suggested that the sea-waters were then less favourable to marine life than at present, owing to a lower temperature. If the observations of the several geologists who have described the pleistocene period and its beds‡ be kept in mind, when considering the raised beds of the West of England and coast of France, it will lead I think to the inference that they also belong to the pleistocene epoch. The raised marine beds of the coasts of Cardigan and Merioneth cannot be separated from the pleistocene beds of Wicklow and the opposite coast. The intervention of the area of the Bristol Channel is not sufficient to cause similar deposits on the north coasts of Somerset, Devon, and Cornwall, to be considered of a different age from those on the Welsh coast. From the Irish Channel to the western coasts of England, and to those of France and the Channel Islands, we have a continuous series of like phænomena; and if one portion is of pleistocene age, so is the whole.

The bearing which this view of the age of these deposits has on the physical history of the English Channel is not without interest. A portion of the pleistocene littoral zone of sea-bed is preserved on the coast of Sussex, where it was first noticed and most accurately described by Dr. Mantell: these beds serve to connect the history of the east and west extremities of the Channel. The Brighton beds contain (as is well known from Dr. Mantell's description, as also to all those who may have examined them) that admixture of foreign crystalline rocks which is so characteristic of the pleistocene accumulations of the

* Report on Devon and Cornwall, pp. 429–646.

† Proceedings of the Geological Society, vol. vii. p. 577.

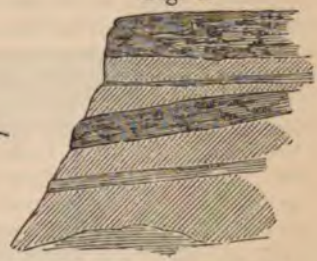
‡ More particularly Mr. Morris on the valley of the Thames.

Eastern counties. These rocks belong to the Northern ocean area, and must have passed from that into the area of the English Channel. We thus arrive at the precise date at which the English Channel became sufficiently depressed so as to be occupied by sea, as well as at the date of the subsidence of the chalk strata along the north and south line before indicated, and which produced the Dover Straits. The movement of the drift materials over the Northern and German ocean area during the pleistocene period was from north to south; and when the Channel valley was opened to the waters of that period, the drift was continued with a like direction into that area: in like manner the chalk-flints of the eastern portions were made to travel west; and in the meagre character of the marine fauna of the raised beds of the Channel, we see that it was influenced by arctic currents, and not southern ones as at present.

The levels of the portions of the littoral zone of the pleistocene period in the English Channel show the depression of that area to have been rather lower at that time than it is at present. There would also appear to have been an intermediate level, of which the shingle bed between Brighton and Rottingdean is a familiar illustration—a level which was of sufficient duration to allow of the formation of cliffs; the Elephant bed, as it is named by Dr. Mantell, belonging to a vast series of deposits, to be noticed in the sequel, and of the age of the drift.

Fig. 3.

Fig. 4.



The drift beds are the uppermost portion of the pleistocene group; and under the name of diluvium were long since traced down into the Thames valley, and fully described as to their characteristic admixture of northern materials by Dr. Buckland. On the south side of the Thames they may be seen extending over the surface of the tertiary district, in many instances overlapping it, and resting on older denuded strata. But as we approach the district where the physical features of the Wealden begin to show themselves, these accumulations diminish in thickness, till at length we reach an area over which no trace whatever of them is to be found. This termination of the pleistocene drift takes place by a well-defined marginal bed, of which clean sections have recently been exhibited in the cuttings of the Reading and Reigate Railway. The detail of about twenty miles of this coast-line, where it ranges across the county of Surrey, will be sufficient, as all that I wish is to connect the phænomena north of the Weald with those on the south. If we commence with this line at Farnham,

we find that the chalk range subsides for an interval, and gives way to a low tract covered superficially with gravel. This accumulation is spread out westward along the valley of the Wey, and abuts against the ridge of lower greensand which bounds the stream, and which evidently defined its limits. In other places the gravels thin out against the slopes of the higher ground, as underneath Crooksbury, where their sides are occupied by it: good instances and sections may be seen, first, in the cutting near the Mill, and on the road to Moor Park, as also in the Pine-wood beyond Waverley: the teeth and the tusks of elephants have been lately met with in these gravels, in extraordinary abundance. The character of the accumulation about Farnham is better conveyed by a woodcut illustration than by verbal description (fig. 3).

From Farnham the gravel beds pass outside the chalk range, and not the slightest trace of them is to be found in the valley between the escarpment of the chalk and the line of hills south of it. At Guildford the gravel passes through the break in the chalk, and is thence spread out over the area of the Peasemarsh (fig. 4), and ends off with an uniform level against the base of the hills which encircle this valley. The remains of elephants, as well as of other animals, are very abundant at this place. The railway-cutting from Guildford to Godalming (fig. 5), and from Shalford to Postford (fig. 6), has given

Fig. 5.

Fig. 6.

sections of these gravel beds; which indicate clearly their marginal character, by the mixture of gravel and shingle with sands diagonally arranged. The boundary-line is here also well-defined.

The condition of this part of England antecedent to the accumulation of the pleistocene beds is well shown in the Peasemarsh: the remains of trees are found beneath the gravels with elephants' teeth and tusks; in one instance so many bones occurred together, in the clay which underlies the gravel, as to warrant the conclusion that an entire skeleton was buried at that spot.

A north and south section from this marginal line of drift, as from Guildford or Farnham to between Brighton and Rottingdean, would show the pleistocene gravels, with characteristic animal remains, end-

ing off at nearly the same level against a central area, over which no trace whatever of such gravels is to be found, and thus insulating it in the pleistocene sea. At Dorking the geological phænomena of the Guildford valley are repeated.

A series of raised marine beds, as already described, surround the West of England on the south-west and west; and except at inconsiderable heights, we find no traces whatever of any drift beds over this area. Here again the highest drift beds with elephants' remains are above the pleistocene beds with shells, as they are on the Sussex coast: such was the position of the Plymouth beds described by Dr. Moore*.

The whole of the South of England, from the Wealden area on the east, to the Land's End, does not appear to have been a continuous line of dry land during the pleistocene period. Between the two tracts here noticed we find a wide interval over which water-worn materials of distant origin occur abundantly. The whole of the valley of the Exe is filled with an accumulation of this sort, derived from the rocks of North Devon; these beds spread out over the country east and west of the actual course of the river, and have afforded elephants' remains from a variety of places and elevations. Dr. Buckland was the first to call attention to the curious fact of the occurrence of pebbles of milky quartz over the highest levels of the Blackdown range. I have described elsewhere the characters by which the bed which contains these pebbles is to be distinguished from all other accumulations of the district, as also the fact of its distinct superposition†; and in spite of the present elevation of the Blackdowns, I see no solution of the difficulty but by supposing that the whole of that area was submerged during the latest portion of the pleistocene period.

The western boundary of this interval of depression, or perhaps better the coast-line of this western island in the latest and highest range of the pleistocene sea, is well defined along the northern extremity of Great Haldon, by a clean outline of water-worn materials and immense blocks, which occur from that point by Whadden Barton, Chudleigh, round the Bovey valley, particularly at Pen Wood, Staple Hill, and thence to Newton. For the evidence that all this material has travelled south—that all the remarkable faults and fissures of the Chudleigh district were produced before the dispersion of this gravel; as well as that the difference of level which it occupies in the Bovey valley and on the summit of the Haldons, is due to changes of level which have taken place since their accumulation, I must refer to a former notice of the district‡. The strongest proof of all, that the highest levels of the Haldons and Blackdowns (900 to 1000 feet) must have occupied a low level with respect to the Dartmoor group, is, that the summit gravel contains pebbles of its schorly granite.

The two areas of the South of England which thus seem to have been insulated in the pleistocene sea, have certain physical features in common, the prominent one being the east and west axes of their mineral masses. The boundary-line of the pleistocene drift from the

* Report of Brit. Assoc. 1841, p. 62.

† Geological Transactions, vol. v. ‡ Ibid.

coast of Belgium runs parallel with the east and west range of the Netherlands; and such also, according to the line traced by M. Berghaus, is its direction across the continent of Europe. South Wales presents a like east and west arrangement, and does not seem to have been submerged. In the South of Ireland again, we have a district where all the physical features are dependent on an east and west direction; and here again the drift beds, which are so widely spread over the rest of Ireland to the northwards, are altogether wanting.

The geographical aspect of the north-west part of Europe at the period of the furthest range of the pleistocene sea would, according to these views, be somewhat such as represented in the map*. The northerly areas of insulation are taken from Prof. E. Forbes, and are in perfect accordance with the pure geological evidence of the greatest amount of depression which the north of this island presents.

In this view I have considered all stratified wide-spread gravels containing elephants' remains to be of the same period with the uppermost pleistocene drift, whether the deposits contained marine shells or not. The elephant remains, so abundant even in the highest pleistocene bed, are commonly treated as those of the animals of that period. These remains occur in the neighbourhood of the Wealden island, and indeed everywhere, under two very different conditions.

1. In the beds of ancient lakes, ponds, or river-beds, where, as at Petteridge, Peasemarsh, Valley of Arun, &c., great quantities of bones and entire skeletons occur.

2. In the sands and gravels of the drift: in these beds the remains consist of the harder portions only, and are mostly water-worn.

A recent examination of the Crag deposits of Suffolk, in company with Mr. Prestwich, Mr. Morris and Mr. Tyler, has satisfied me that the change from pliocene to pleistocene conditions took place by gradual subsidence, and consequent decrease of the area of dry land of England which was contiguous to the pliocene sea; that this was attended by a diminishing temperature; and that the marine conditions, so far as animal life was concerned, had assumed their arctic character long before the whole of Northern Europe had reached its greatest amount of depression. The remains of the land animals have, in the case of the drift beds, been derived from the sweeping of the surface of the area of dry land over which the pleistocene waters spread, and over which surface such remains might have been accumulating for countless ages. These, and the remains in the bone-caves, represent the fauna of the whole period during which the principal part of this island was in the condition of dry land.

The period at which we have clear evidence of the area of the Channel having been occupied by sea, is separated from the eocene formations by such a long lapse of geological time, that a glance at its condition during the interval forms a necessary part of its physical history. I endeavoured to show, in a former paper on part of South Devon†, that along every valley through which a river

* Exhibited when the paper was read, but not included in the illustrations.

† Geological Transactions, vol. v.

takes its course, alluvia are to be found at elevations such as the existing streams never attain. At that time I was disposed to refer these former broad river-courses to the period of the so-called raised beaches. I have recently had an opportunity of re-examining some of these valleys, and of looking at like phænomena in other places, and I now feel satisfied that the two classes of accumulation are perfectly distinct as to time.

The volume of the rivers of a district depends directly on the amount of moisture precipitated over it, and this depends on its elevation above the sea; so that to depress any given area will not tend to increase its rivers. There are other objections apart from this general one; if we take any river-course opening out into the English Channel, such as that of the Dart, and suppose a depression of the land to take place of 100 feet, we should obtain a great extension of the estuary portion of such river, which portion would be permanently characterized by its cliffs and accumulations. This new water-level, though it might account for estuary beds and shells at a higher level than before, would have no influence on the upper portions of the streams flowing down into such estuary, so as to augment their volume. In the valley of the Dart, however (as well as in all the others), there is no indication whatever of any estuary beds at higher levels than the present ones; but the ancient alluvia, which conform to the dimensions of the valley, and are distinguishable from the recent by their coarse torrential character, as well as breadth, can be traced by Holne Bridge and Staverton, till they pass down beneath the accumulations of the present estuary. These observations apply to every river of the West of England; none of them show estuary beds above the present water-level, but their upper portions show alluvia which are.

The conditions which alone will account for these appearances are obvious—the country, instead of having been placed at a lower level at the period of these broad alluvia, had a much greater elevation above the sea, and when the sea did not reach such portions of these valleys as it does now. This condition is not local, but is applicable to every considerable river-course in the island, along every one of which we can find indications of the larger dimensions of the former rivers. The Thames and the Severn are striking examples.

That the whole area of the English Channel had at one time a higher level, is directly proved by the numerous instances along its shores where old forest ground passes beneath the present sea-bed: these are marked on the map. It seems to be constantly assumed that the original position of these wooded tracts was close to the coast-line, or at the sea-level; but for such a supposition there seem to be no grounds whatever. Proximity to the sea is generally unfavourable to the growth of timber. If we take the whole line of the coasts of the Channel on either side, we shall not find any wooded tracts coming down to it, or even single trees of any magnitude; yet in many instances the trees of these submerged lands had attained a very great size. Again, the trees which have been identified from these submerged woods, such as the elm, oak, chestnut, hazel, are none of them such as have their usual habitats along the sea-board. But per-

haps the strongest argument is from the presence of the *Pinus sylvestris*: its natural zone of growth, requisite condition of soil, great susceptibility of the influence of sea-air, alike point to the improbability of its having grown in masses, or attained any size, in the vicinity of the sea.

The conclusion we may safely arrive at is, that the area of the present English Channel was in the condition of dry land previous to its occupation by the waters of the pleistocene sea, or during the period of the pliocene (crag) accumulations of the German basin, and that, together with a large area beyond, it served to connect the British Islands with France on the south, and Ireland on the west, into a tract which had a far greater amount of elevation than any portion of it has at present.

The geologist will require that many conditions resulting from such a state of things should have left their evidences. At many places along the shores of the Channel, thick accumulations of earthy materials come down to the sea-level. The western coast affords the best opportunities for studying these beds. The bold coast-line from the Start Point westwards presents a yellow band rising from the raised high-water, and which might at first sight be taken for a line of brick-marine beds: from the Start to the Prawle this bed expands in thickness, and forms a low cliff of loose uncemented materials upwards of twenty feet thick. The whole of this accumulation is the result of the disintegration of the rocks of the district: throughout the whole thickness of the mass, but without any defined arrangement, occur fragments and angular blocks of all sizes, some containing several cubic feet. The accumulation is strictly local; along the whole of this line of section the angular fragments have evidently been detached from the chlorite slate precipices which overhang it, nor does it afford a single pebble which would indicate attrition by water.

Following these beds to the mouth of the Erme, they are found on either side of the entrance, above the high-water level, whilst inland it is clearly seen that the area of the present estuary has been excavated out of this accumulation.

In every one of the Channel Islands group a like accumulation comes down to the sea-level, and from the more rapid disintegration of the crystalline rocks, its thickness is often very great. Here again we meet with repeated illustrations of the local character of the accumulation, that the angular blocks have merely fallen from masses of rock immediately above, without the slightest indication of horizontal movement.

These accumulations are due to *subaërial conditions*, continued through a vast lapse of time, and dating back to periods long anterior to the present relative position of land and sea. The thickness of these beds increases westwards, and as atmospheric agency is greater as the elevation of the land on which it is exercised increases, it adds one more argument to many others in favour of the view, that at the period of greater elevation that of the west of England was most considerable.

In the foregoing considerations, which the study of the area of the

English Channel suggests, I have endeavoured to confine myself to those which belong to pure geology. I might however have borrowed great aid from a branch of inquiry first imagined by Prof. E. Forbes —that of the relation which an existing flora may bear to past geological changes*. I would suggest whether it may not be sufficient to reduce the existing fauna and flora of this country to two periods of origin; one which has come in since the period of the glacial drift, the other that which forms the local character of several districts, which we have shown were insulated in the pleistocene ocean, and which flora has outlived all subsequent changes. In this way the characteristic plants of the south of England and Ireland† will be the residual portion of that of the pliocene period, which corresponds with that of the greatest amount of area and elevation. The Scandinavian character of the floras of part of Wales, the Lake district‡, and more particularly the north of Scotland, will, under this supposition, be the remains of the alpine regions of the same period.

The condition of surface prior to the overlap of marine pleistocene accumulations is indicated by the remains of vegetation so constantly found beneath the drift with elephants' remains; but traces of this vegetation are also met with (as over the Wealden) in tracts which the pleistocene waters never reached. Of the remains of this antecedent vegetation, the *Pinus sylvestris* is perhaps the most characteristic. Undoubted trees of this species, and of great size, occur over the surface of the Wealden denudation, buried in old peat bogs, and are remarkable for the great thickness of their bark—a character which becomes marked in proportion as the tree advances to a colder region.

The period of the terrestrial conditions of greatest cold over the area of Great Britain would therefore be, when it was part of an area of much greater extent, and at a much greater elevation. With this extended area, and absence of internal seas, there would be, as compared both with the pleistocene and present condition, an excessive or continental climate. The character of the flora of such a geographical condition would be at the same time more southern and more northern. Much of what now constitutes upland sandy tracts devoid of vegetation, from insufficient moisture, would then have been included in the regions of pines and forests, of which the buried Scotch and spruce firs are the remains.

In like manner the period of the marine conditions, with a meagre fauna, would be that of the greatest amount of depression and expanse of sea. From what has gone before we may infer that the process of submergence during the pleistocene period was gradual and progressive from north to south, the marine fauna being such as waters coming in such a direction would bring with them: the terrestrial and marine periods of minimum temperature do not therefore correspond in geological time.

Even at the period of greatest depression, the *Pinus sylvestris* might continue to live on over the northern insulated part of the

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An examination of those portions of the several formations which occur within short distances of the coast-line of the Channel valley on either side, tends strongly to establish the supposition of a recurrence of like conditions along the same area at several distinct geological epochs.

The thick beds of shingle at certain places in South Devon (Ugbrook, Connator, &c.) indicate the proximity of the littoral zone of the carboniferous deposits; these beds occur upon a group of strata, which again indicate a series of antecedent local elevations, attended with the diffusion of trappean matter, over which zoophytes constructed the Devonian coral reefs: on the other side of the Channel the limestone masses of the Cotentin were evidently formed under like conditions, and at the same time: lower than these in the same series occurs the coarse shingle of the French and Jersey slate rocks.

At the subsequent period of the new red sandstone, the lower beds constantly suggest conditions of marginal accumulation: the movement which attended the accumulation was one of gradual subsidence, but the sheet of porphyritic matter which contributed so much material to the new red conglomerate must have been for a considerable period at the water-level, as high in the series, and after an enormous amount of accumulation, large blocks of porphyry have been thrown down over beds which from their composition must have been deeper-water deposits than such as occur beneath them. The condition of the materials along the edge of the new red sandstone group in Calvados and La Manche is often that of true shingle, of great thickness, composed of the quartzose rocks of the district. The older strata of this part of France run east and west, and this elevation was acquired before the new red sandstone period; so that we seem to have the direction of an area of dry land east and west, and that of a line of coast shingle conforming to it. From this coast-line the new red sandstone sea stretched away north and east with an increasing depth, except where, as in South Devon and Somerset, islands presenting coast-masses of limestone or porphyry rose to the surface, from the spoil of which the coarse conglomerates were formed. The great blocks of porphyry of the middle beds of the new red series in the West of England, included in sands and marls, indica-

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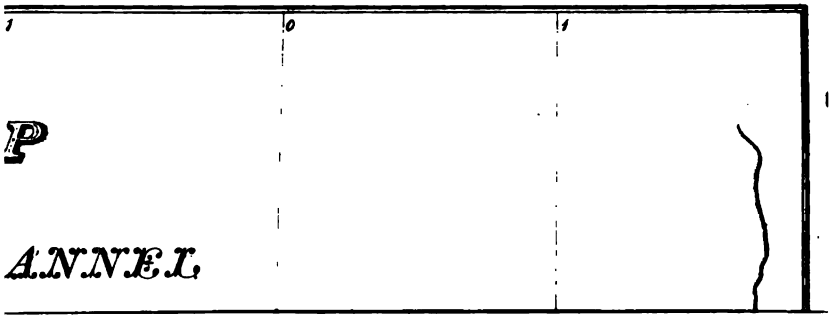

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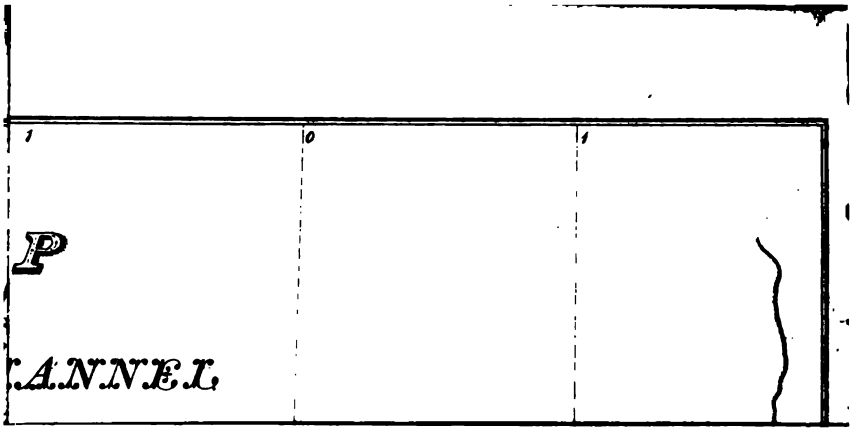
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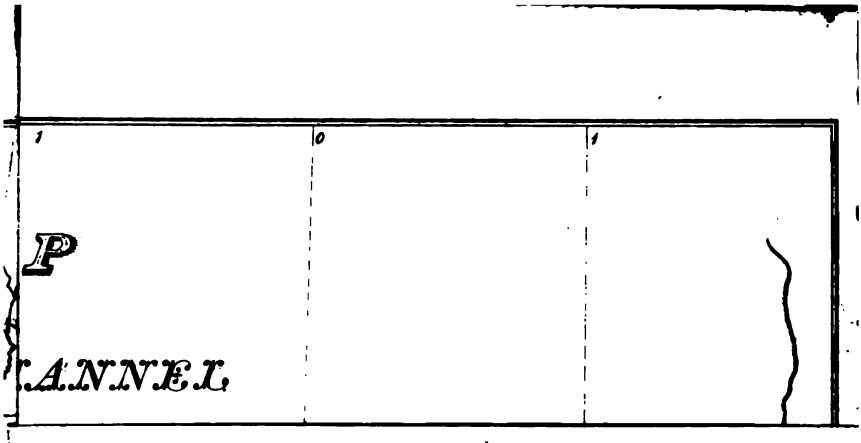
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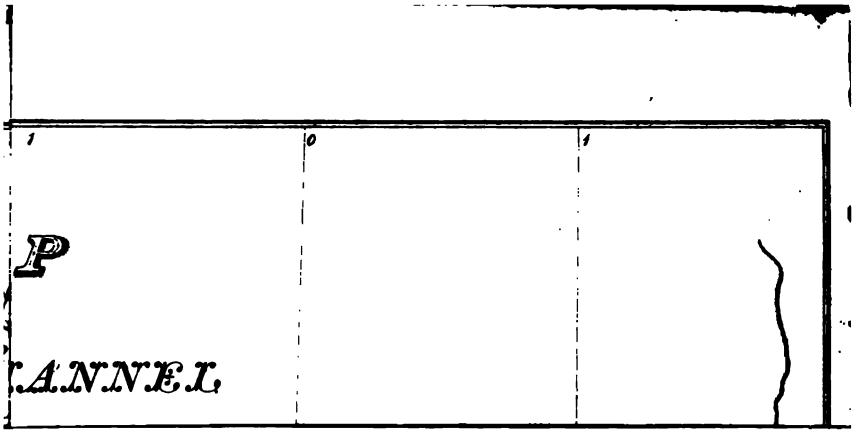
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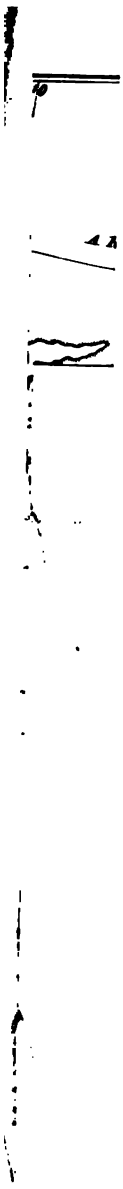

ting no great moving power, seem to require some such agent as that of floating ice to account for their position.

Terrestrial conditions of great geographical extent, and of long duration, intervened between the oolitic and cretaceous periods: the Wealden strata of Sussex, Isle of Wight and Dorset indicate clearly, by the interchange of marine and freshwater conditions, that the Wealden area was at the sea level, or at the lowest portion of the area of dry land to which it was subordinate. It is not necessary to consider the direction of the dry land of the period; it is sufficient that no beds of the Wealden age underlie the Neocomian deposits from Trouville to Cape la Heve: the slight and even questionable traces of the Wealden in the Boulonnais show that it had its limit in that direction. The palæozoic series of the Boulonnais had received, long prior to this, the features of elevation and folding which it now presents; the line of this disturbance extends eastwards: if prolonged west it would pass along the English Channel, which, being occupied by the lower oolitic groups, whilst the Boulonnais presents only the middle and upper, prove it to have been relatively an area of depression.

Coarse rounded shingle formed of local materials, such as of the siliceous bands of the carboniferous deposits, occurs abundantly at the base of the greensand beds west of the Haldon Hills. The equivalent beds in the Cotentin are also a shallow-water accumulation.

Terrestrial conditions again obtained during the course of the eocene accumulations; but the freshwater deposits of Hampshire and the Isle of Wight, and which are entirely included in the area of the present Channel, indicate, by the alternation of marine, brackish, and freshwater conditions, a like position with respect to the area of eocene dry land, which the Wealden lake had presented before at the same place.

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DONATIONS

TO THE

LIBRARY OF THE GEOLOGICAL SOCIETY,

July 1*st to October* 31*st*, 1849.

I. TRANSACTIONS AND JOURNALS.

Presented by the respective Societies and Editors.

Agricultural Society (Royal) of England, Journal of. Vol. x. part 1. no. 23.

American Academy of Arts and Sciences. Vol. ii. pp. 1–160.

——— Association for the Advancement of Science, Proceedings of First Meeting of.

——— Journal. Second Series, vol. viii. nos. 22 and 23.

——— Philosophical Society, Proceedings of. Vol. v. no. 42.

Asiatic Society (Royal), Journal of Bombay Branch. No. 12, 1849.

Astronomical Society, Memoirs of, vol. xvii. Monthly Notices, vol. viii.

Belgique, Académie Royale de. Mémoires, tome xxiii. Bulletins, tome xv. partie 2, and tome xvi. partie 1. Annuaire, 1849. Mémoire sur la Fertilization des Landes de la Campine et des Dunes ; par M. Eenens.

Berlin Academy, Abhandlungen for 1849. Bericht, from July 1848 to June 1849.

British Association, Report of the Eighteenth Meeting of the.

Calcutta Public Library, Catalogue of, 1846.

Chemical Society, Quarterly Journal of. Nos. 6, 7.

Dublin, Journal of the Geological Society of. Vol. iv. part 1.

Edinburgh, Transactions of the Royal Society of. Vol. xvi. part 5, and vol. xix. part 1.

France, Société Géologique de, Bulletin. Deux. Série, tome iv. f. 87–92 ; t. 6. f. 19–26.

Genève, Mémoires de la Société de Physique et d'Histoire Naturelle de. Tome xii. partie 1, and supplements 1 and 2.

Geographical Society (Royal), Journal of the. Vol. xix. part 1.

Horticultural Society, Transactions of the. Second Series, vol. i. parts 3, 4, 5, 6 and 7; vol. ii. parts 1–6, and vol. iii. parts 1, 2, 3. Journal of, vol. iii. parts 3, 4, and vol. iv. parts 1, 2, 3.

London, Edinburgh, and Dublin Philosophical Magazine. Nos. 233–237.

Mauritius, Transactions of the Royal Society of Arts and Sciences of. Vol. i. parts 1 and 2.

Palæontographical Society, Monographs published by the. Of the Fossil Reptilia of the London Clay, Part 1. Chelonia, by Professors Owen and Bell. Of the Eocene Mollusca, by F. E. Edwards, Part 1. Cephalopoda.

Paris, Academy of Sciences of. Comptes Rendus. Nos. 1–24 and 26. Tome xxviii. Prem. Sém.; index to tome xxvii., and tome xxix. Deux. Sém., nos. 2–14.

Royal College of Surgeons, List of Fellows and Members of, for 1849.

Royal Society, Philosophical Transactions of the. 1846, part 4; 1847, parts 1 and 2; 1848, parts 1 and 2; 1849, part 1. Proceedings, nos. 66–72. List, Nov. 1848. President's Address, June 1848.

Smithsonian Contributions to Knowledge, vol. i., Reports, &c. 1849.

Van Diemen's Land, Royal Society of, Papers and Proceedings, vol. i. part 1. Report for 1848. Rules, &c. for 1848.

Zoological Society, Reports of the Council and Auditors of, 1849.

II. GEOLOGICAL AND MISCELLANEOUS BOOKS.

Names in italics presented by Authors.

Austin, Thomas. Monograph of Recent and Fossil Crinoidea. No. 8.

Buch, L. von. Betrachtungen über die Verbreitung und die Grenzen der Kreide-Bildungen.

Carter, H. J. A descriptive account of the Freshwater Sponges in the Island of Bombay.

————. On Foraminifera in Arabia, Surdh, &c.

Dana, J. D. Synopsis of the Genera of Gammaracea.

————. Conspectus Crustaceorum, &c.

Fairbairn, W. An Account of the Construction of the Britannia and Conway Tubular Bridges.

Forbes, J. D. Travels through the Alps of Savoy and other parts of the Pennine Chain, with a Map of the Mer de Glace.

Garner, R. The Natural History of the County of Stafford.

Göppert, Prof. Uebersicht der Arbeiten und Veränderungen der Schlesischen Gesellschaft für vaterländische Kultur im Jahre 1848.

Guyot, Prof. A. The Earth and Man.

Hutton, Capt. T. Notes on the Geology and Mineralogy of Affghanistan. (2 copies.)

———. Apparent Objections to the Glacial Theory. (2 copies.)

Johnson, J. F. H. Contributions to Scientific Agriculture.

Kutorga, Dr. S. Ueber die Siphonotretæe und einige Baltisch-Silurische Trilobiten.

Logan, J. R. The Rocks of Pulo Ubrio.

———. The Languages of the Indian Archipelago.

Logan, W. E. Geological Survey of Canada, Report of Progress for the year 1847–48.

Mantell, G. A., LL.D. Observations on the Osteology of the Iguanodon and Hylæosaurus.

Newbold, Capt. Summary of the Geology of Southern India. Part 11.

Pattison, S. R. Chapters on Fossil Botany.

Quetelet, A. Sur le Climat de la Belgique. Trois. partie.

Reid, Lieut.-Col. W. The Progress of the Development of the Law of Storms, and of the Variable Winds, &c.

Review of "Statistics of Coal," by R. C. Taylor. From Edin. Review, Oct. 1849. Presented by William H. Fitton, M.D., F.G.S.

Unger, Prof. Plates 1 and 2 of the Tableaux Physionomiques de la Végétation des diverses périodes du monde primitif.

THE

QUARTERLY JOURNAL

OF

THE GEOLOGICAL SOCIETY OF LONDON.

PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

NOVEMBER 7, 1849.

The following communications were read:—

1. *Remarks on the Genus* NERINÆA, *with an Account of the Species found in* PORTUGAL. By DANIEL SHARPE, Esq., F.G.S.

THE genus *Nériné* was proposed by M. Defrance, in the 'Dictionnaire des Sciences Naturelles,' for certain species of turreted univalves found among the oolites, distinguished by having both the columella and the interior of the outer lip furnished with folds which are continued through the whole of the whorls; but as M. Defrance had not then seen any perfect specimens, he did not give any strict definition of his new genus.

M. Deshayes gave definite characters to the genus under the name of *Nerinæa*, in the 'Coquilles caractéristiques des Terrains,' p. 203, the principal points of which are the mouth subquadrangular? canaliculated; a broad umbilicated columella with strong spiral folds; and one or more folds on the interior of the outer lip.

Thus far the genus presents well-defined limits; and if we omit the perforation of the columella from its distinctive characters, it consists of a natural group of species. But succeeding authors

have broken through all the boundaries of the genus laid down by M. Deshayes, and admitted many species which do not come under his definition of *Nerinæa*. Voltz, who has added largely to our knowledge of the species, includes in *Nerinæa* shells with a rhomboidal mouth and at least one internal fold (Jahrbuch, 1836, p. 538), thus admitting *N. grandis* and *N. depressa*, which have only a fold on the columella, and have the outer lip simple: in this he is followed by Bronn, and practically also by Goldfuss, who, while defining the genus as having folds both on the columella and the outer lip, places in it *N. pyramidalis* and *N. subpyramidalis* with only a fold on the columella. M. d'Hombres-Firmas and M. d'Orbigny have since added *N. brevis*, a shell without any internal fold whatever.

M. d'Orbigny* has given a full description of the mouth of *Nerinæa* provided with an anterior and a posterior canal, and has pointed out that in this genus the whorls increase rapidly in size while the shell is very young, and afterwards continue of nearly the same diameter: this gives all the species of *Nerinæa* a certain general resemblance, by which they are easily recognised; and it follows from this peculiarity that the old shells are nearly cylindrical when the columella is solid, and that in the species of pyramidal form the increase in diameter is obtained by leaving a conical umbilicus down the columella.

The remarkable thickening of the internal folds in the upper part of the shell has been frequently noticed: in some species the animal continued to add calcareous matter to these folds till they nearly filled the upper whorls, which then appear to have been abandoned and perhaps to have decayed and worn off; among the larger cylindrical species of *Nerinæa* we rarely find an old shell with its spire perfect.

Most of the shells which have been placed by different authors in the genus *Nerinæa* are so closely connected together, that they obviously belong to one group, which unites the rhomboidal opening of the *Trochi* to the two canals of the mouth of the *Cerithia*, thus forming a link between those genera; and of which the nearest living analogue is the *Cerithium telescopium*, formed by De Montfort into the genus *Telescopium*. Yet this group now contains shells of such different characters that it has become desirable to divide it either into separate genera or sections. The species admit of arrangement in four natural divisions, which may be regarded for the present as subgenera, and may be defined as follows:

Subgenus 1. Nerinæa.

Columella with two or three folds; outer lip with one or two folds; the folds all simple; the columella solid or umbilicated.

This division contains the typical umbilicated species of Defrance and Deshayes; but it cannot be limited to the umbilicated species

* Paléontologie Française, Terrains Cretacés, vol. ii. p. 72.

only, as the perforation of the columella is not accompanied by any other constant character, and the umbilicated and non-umbilicated species can hardly be distinguished; moreover *N. Voltzii* of Deslongchamps has the columella solid when young and perforated in its older stages. More than half the known species of *Nerinæa* fall into this division.

Fig. 1 is the section of a portion of *N. Archimedis*, D'Orb., from near Cintra, which illustrates the internal characters of this subgenus.

Fig. 1.

Fig. 2.

Subgenus 2. NERINELLA.

Columella solid, either simple or furnished with one fold; the outer lip with one internal fold; folds simple; the mouth usually much longer than wide; the shell nearly cylindrical or very taper.

The species of this section are not numerous; they have not the characters laid down by the founders of the genus, but are obviously closely related to it: they are usually small and very elongated.

Fig. 2 represents a section of part of *N. Dupiniana*, D'Orb., copied from the 'Paléontologie Française' to illustrate this subgenus.

Subgenus 3. TROCHALIA*.

Columella umbilicated, with one fold; mouth rhomboidal; the outer lip either simple, or thickened internally, or furnished with one internal fold; folds simple; the shell usually short and conical.

These species differ widely from the original type of the genus, and approach the *Trochi*; they are usually of large size, without any

* Named from its resemblance to *Trochus*. Τροχαλία, *a water-wheel*.

ornament, and of a conical or pyramidal form, with a wide umbilicus: they are not numerous.

Fig. 3 shows the section of the interior of *N. grandis*, Voltz, from Alenquer, belonging to this group.

Fig. 3.

Fig. 4.

Subgenus 4. PTYGMATIS *.

Columella either solid or umbilicated, usually with three folds; outer lip with one to three folds; one or more of the folds of a complex form, either dividing into two lobes, or wider towards the edge than at the base.

If we only looked to the number and position of the internal folds, the species of this division would be united to the true *Nerinææ* of the first section; but they form a very natural group, distinguished by the complicated form of the folds, which, instead of being enlarged by deposits of shelly matter along their base and sides, as in the other three sections, were principally enlarged towards their edges: in the upper whorls this enlargement of the folds was carried on to such an extent that they nearly fill up the interior of the shell, and leave a narrow passage of a most complicated form for the body of the animal, which gives a very whimsical appearance to the sections of the shells. Externally the shells are of a taper or nearly cylindrical form, with very little ornament, and the species can only be distinguished conveniently by a section.

Fig. 4 shows a section of *N. Bruntrutana*, Thurm., from Alenquer, to illustrate this subgenus.

The following lists contain all the well-defined species of *Nerinæa*, of which descriptions have been met with, arranged under their respect-

* From πτύγμα, *a fold or plait*.

ive subgenera; and a list is added of shells which have been placed in this genus, but which it is conceived belong to other genera.

Subgenus 1. Nerinæa.

Columella with two or three folds; outer lip with one or two folds; folds all simple.

A. *Columella solid.*

a. *One fold inside the outer lip; two folds on the columella.*

N. Archimedis, D'Orb. T. Cret. t. 158. f. 3, 4.
N. Aunisiana, D'Orb. T. Cret. t. 160. f. 8, 9.
N. Bronnii, Goldf. t. 177. f. 4.
N. Carteroni, D'Orb. T. Cret. t. 160. f. 1, 2.
N. Chamouseti, D'Orb. T. Cret. t. 159. f. 1, 2.
N. cingenda, Phillips, G. Yorksh. vol. 1. t. 11. f. 28, 29.
N. clavus, Deslongch. Mém. Soc. Linn. Norm. 7. t. 8. f. 28, 29; *N. Goodhallii*, Deslongch. *l. c.* t. 8. f. 25; not of Sowerby. *N. fibula*, Deslongch. *l. c.* t. 8. f. 26, 27.
N. Coquandiana, D'Orb. T. Cret. t. 156. f. 3, 4.
N. cylindrica, Voltz et Bronn, Jahrb. 1836, p. 542. t. 6. f. 16.
N. cylindrica, Deslongch.; vide *N. funiculus*.
N. Eichwaldiana, D'Orb. Géol. Russie et l'Oural, 2. t. 37. f. 7.
N. elegans, Thurmann, Porrentr. 17; Voltz et Bronn, Jahrb. 1836, p. 542. t. 6. f. 20.
N. elongata, Voltz et Bronn, Jahrb. 1836, t. 6. f. 15.
N. Espaillaciana, D'Orb. T. Cret. t. 164. f. 2.
N. gigantea, D'Hombres-Firmas, Mém.; D'Orb. T. Cret. t. 158. f. 1, 2.
N. Goodhallii, Sow. Tr. Geol. Soc. 2nd ser. 4. t. 23. f. 12. *N. suprajurensis*, Voltz et Bronn, Jahrb. 1836, t. 6. f. 3, not f. 2; Goldf. t. 175. f. 10.
N. involuta, Bronn, Jahrb. 1836, t. 6. f. 25.
N. lobata, D'Orb. T. Cret. t. 160. f. 3.
N. nodulosa, Desh. Exp. Morée, t. 26. f. 6, 7.
N. nodulosa, Deslongch. Mém. Soc. Linn. Norm. 7. t. 8. f. 23, 24; not of Deshayes.
N. punctata, Bronn, Jahrb. 1836, t. 6. f. 23.
N. Rœmeri, Philippi, Jahrb. 1837, t. 3. f. 1, 2; Goldf. t. 176. f. 5; anne *fasciata*, Rœmer?
N. simplex, Desh. Exp. Morée, t. 26. f. 4, 5.
N. speciosa, Bronn, Jahrb. 1836, p. 560.
N. subteres, Goldf. t. 175. f. 6.
N. suprajurensis *, Voltz, sp.; Bronn, Lethæa, t. 21. f. 12; Voltz et Bronn, Jahrb. 1836, t. 6. f. 2, not f. 3. *N. Defrancii*, Desh. Exp. Morée, t. 26. f. 1, 2; anne *N. Archimedis*, D'Orb.?

* Voltz and Bronn have confounded two species under the name of *N. suprajurensis*: their fig. 3 is the *N. Goodhallii*, Sow.; fig. 2 appears to be the same as *N. Defrancii*, Desh., and possibly as *N. Archimedis*, D'Orb.: without seeing the specimens it would be dangerous to speak positively. D'Archiac's shell appears to be different from both.

N. suprajurensis, D'Archiac, Mém. Soc. Géol. de France, vol. 5. t. 30 f. 10.
N. terebra, Ziet. t. 36. f. 3; Goldf. t. 175. f. 13.
N. Titan, nobis, t. 12. f. 3.

b. *One fold inside the outer lip; three folds on the columella.*

N. bicincta, Bronn, Jahrb. 1836, t. 6. f. 14.
N. flexuosa, Sow. Trans. Geol. Soc. 2nd ser. 3. t. 38. f. 16; Bronn Jahrb. 1836, t. 6. f. 19; Goldf. t. 177. f. 7.
N. funiculus, Deslongch. Mém. Soc. Linn. Norm. 7. t. 8. f. 30–32 *N. acicula*? D'Archiac, Mém. Soc. Géol. de France, vol. 5. t. 30 f. 6, 7. *N. cylindrica*, Deslongch. *l. c.* t. 8. f. 33; not of Voltz
N. incavata, Bronn, Jahrb. 1836, t. 6. f. 22.
N. nobilis, Goldf. t. 176. f. 9; *post*, t. 12. f. 1.
N. nodosa, Voltz et Bronn, Jahrb. 1836, p. 542. t. 6. f. 9.
N. Pailletteana, D'Orb. T. Cret. t. 161. f. 1–3.
N. pauperata, D'Orb. T. Cret. t. 161. f. 6, 7.
N. regularis, D'Orb. T. Cret. t. 160. f. 10.
N. Requieniana, D'Orb. T. Cret. t. 163. f. 1–3.
N. subscalaris, Goldf. t. 175. f. 12.
N. trinodosa, Voltz et Bronn, Jahrb. 1836, p. 540. t. 6. f. 10.

c. *Two folds inside the outer lip; three folds on the columella.*

N. ampla, Goldf. t. 176. f. 10.
N. Podolica, Pusch, Poln. Pal. t. 10. f. 17; Bronn, Jahrb. 1836 t. 6. f. 11.
N. teres, Goldf. t. 176. f. 3.
N. uchauxiana, D'Orb. T. Cret. t. 164. f. 1.

B. *Columella umbilicated.*

a. *One fold inside the outer lip; two folds on the columella.*

N. Geinitzii, Goldf. t. 177. f. 8. *N. Borsoni*, Geinitz, Sächs. Kreide geb. t. 14. f. 6, 7; Rœmer, Kreidegeb. t. 11. f. 8.
N. Renauxiana, D'Orb. T. Cret. t. 157.
N. Sequana, Thirria, p. 7; Voltz et Bronn, Jahrb. 1836, t. 6. f. 6 Goldf. t. 176. f. 7.
N. Visurgis, Rœmer, Ool. t. 11. f. 26, 28; Voltz et Bronn, Jahrb 1836, t. 6. f. 8; Goldf. t. 176. f. 6.
N. Voltzii, Deslongch. Mém. Soc. Linn. Norm. 7. t. 8. f. 34.

b. *One fold inside the outer lip; three folds on the columella.*

N. Bauga, D'Orb. T. Cret. t. 162. f. 1, 2.
N. bicincta, Bronn, Jahrb. 1836, t. 6. f. 14; Goldf. t. 177. f. 5;—i this umbilicated?
N. elegans. Helicoceras, sp. Kœnig, Icon. Sect. 249.
N. grandis, Goldf. t. 175. f. 8; not of Voltz and Bronn.

c. *Two folds inside the outer lip; three folds on the columella.*

N. Mosæ, Desh. Coq. Caract. t. 4. f. 1, 2.

C. *Internal structure imperfectly known.*

N. Borsoni, Catullo sp. Bronn, Jahrb. 1836, t. 6. f. 12.
N. cincta, Goldf. t. 177. f. 12.
N. dubia, D'Archiac, Mém. Soc. Géol. France, 2nd ser. vol. 2. t. 25. f. 4.
N. excavata, Brongniart sp. Env. Paris, t. 9. f. 10. *Turritella concava*, Sow. Min. Conch. t. 565. f. 5.
N. Gosæ, Rœmer, Ool. t. 11. f. 27; Bronn, Lethæa, t. 21. f. 11; Goldf. t. 175. f. 9.
N. margaritifera, D'Archiac, Mém. Soc. Géol. de France, vol. 5. t. 30. f. 4.
N. sulcata, Ziet. t. 36. f. 4.
N. tuberculosa, Rœmer, Ool. t. 11. f. 29.
N. turritellaris, Goldf. t. 177. f. 3.
N. unicarinata, Woodward sp. Geol. Norf. t. 6. f. 21.

Subgenus 2. NERINELLA.

Columella solid, either simple or with one fold; outer lip with one internal fold; mouth longer than wide; shell taper or nearly cylindrical.

A. *Columella simple.*

N. Matronensis, D'Orb. T. Cret. t. 159. f. 9, 10.
N. subæqualis, D'Orb. T. Cret. t. 162. f. 5, 6.

B. *Columella with one fold.*

N. constricta, Rœmer, Ool. t. 11. f. 30; Bronn, Jahrb. 1836, t. 6. f. 4; Goldf. t. 175. f. 11.
N. Dupiniana, D'Orb. T. Cret. t. 159. f. 5–8.
N. granulata, Goldf. t. 177. f. 6.
N. quadricincta, Goldf. t. 176. f. 4.

C. *Internal structure imperfectly known.*

N. fasciata, Rœmer, Ool. t. 11. f. 13; Voltz et Bronn, Jahrb. 1836, t. 6. f. 21.
N. pulchella, D'Orb. T. Cret. t. 161. f. 4, 5.
N. Royeriana, D'Orb. T. Cret. t. 159. f. 3, 4.
N. subcochlearis, Goldf. t. 175. f. 14.

Subgenus 3. TROCHALIA.

Columella umbilicated with one fold; outer lip either simple or with one internal fold; shell usually conical.

A. *Outer lip straight and simple.*

N. depressa, Voltz et Bronn, Jahrb. 1836, t. 6. f. 17.
N. pyramidalis, Goldf. t. 176. f. 11.
N. subpyramidalis, Goldf. t. 175. f. 7.

B. *Outer lip deeply depressed in the middle and thickened internally.*

N. annulata, nobis, t. 13. f. 1.
N. grandis, Voltz et Bronn, Jahrb. 1836, t. 6. f. 1; not of Goldfuss.

C. *Outer lip furnished with an internal fold.*

N. turbinata, nobis, t. 12. f. 2.

Subgenus 4. Ptygmatis.

Columella usually with three folds; outer lip with one to three folds; one or more of the folds of a complex form, either dividing into two lobes, or wider towards the edge than at the base.

A. *Columella solid.*

N. bifurcata, D'Orb. T. Cret. t. 160. f. 4, 5.
N. Conimbrica, nobis, t. 13. f. 4.
N. Eschwegii, nobis, t. 13. f. 2.
N. Fleuriausa, D'Orb. T. Cret. t. 160. f. 6, 7.
N. Olisiponensis, nobis, t. 13. f. 3.
N. triplicata, Voltz et Bronn, Jahrb. 1836, t. 6. f. 24.

B. *Columella umbilicated.*

N. Bruntrutana, Thurm. 17; Bronn, Lethæa, t. 21. f. 13; Voltz et Bronn, Jahrb. 1836, t. 6. f. 13, 18; Goldf. t. 175. f. 5. *N. hieroglyphica*, Lyell, Elem. Geol. 2. p. 48. f. 246.
N. Bruntrutana, D'Archiac, Mém. Soc. Géol. de France, vol. 5. t. 30. f. 11.
N. crenata, Goldf. t. 177. f. 2.
N. imbricata, Desh. Exp. Morée, t. 26. f. 4, 5.
N. Mandelslohi, Bronn, Jahrb. 1836, t. 6. f. 26; Goldf. t. 175. f. 4.
N. trachæa, Deslongch. Mém. Soc. Linn. Norm. 7. t. 11. f. 2, 3.
N. Voltzii, D'Archiac, Mém. Soc. Géol. de France, vol. 5. t. 30. f. 5; not of Deslongchamps.

The following species, which have been placed in *Nerinæa*, appear to belong more properly to other genera:—

N. brevis, D'Hombres-Firmas; D'Orb. Terr. Cret. t. 162. f. 3, 4; has no internal fold, nor the mode of growth of the *Nerinææ*: as only a cast has been figured it is difficult to decide on its true genus, which may be *Trochus* or *Pleurotomaria*.

N. Marrotiana, D'Orb. T. Cret. t. 163 bis, f. 1, 2, has the folds on the columella only formed at certain intervals, as in *Pyramidella*.

N. monilifera, D'Orb. T. Cret. t. 163. f. 4, has only a fold on the top of the whorl, with the columella and the outer lip simple, as in *Telescopium*.

N. perigordina, D'Orb. T. Cret. t. 163 bis, f. 1, 2, belongs to *Cerithium*, having the outer lip simple, and a fold on the columella, which, according to the figure, is not continued through the whorls.

N. pulchella, Thurm. Porrentr. 17, is a *Cerithium* according to Voltz and Brown, Jahrb. 1836, p. 566.

N. quinquecincta, Goldf. t. 176. f. 2; probably a *Cerithium*?

N. tricincta, Goldf. t. 176. f. 1, is a *Cerithium*.

N. turritella, Goldf. t. 176. f. 5, is also a *Cerithium*: these two last have only a fold on the columella, which may be seen in *C. giganteum*, *C. cornucopiæ*, &c. continued throughout the spire.

The fossil remains of *Nerinæa* are usually found in company with corals, Ostreæ, Pectens, and other shells supposed to have been natives of shallow seas; and rarely near many Terebratulæ or Ammonites. It is probable, therefore, that they were littoral animals. They are most common in beds of limestone, are seldom seen in sandstones, and still more rarely in clays.

In England we have in the different beds of oolite many species of *Nerinæa*, but only one, *N. Goodhallii*, which attains a considerable size; and there are only one or two very small species known in the cretaceous system.

In the North of Germany, according to Rœmer, the oolitic series furnishes several species of *Nerinæa* of middling size; but only one species is known in the greensand, and none in the chalk.

In the South of Germany, Voltz and Goldfuss have published several large and small species both from the oolitic and the cretaceous systems.

In France the oolitic species of *Nerinæa* are large and numerous, but they have been but imperfectly described. M. D'Orbigny's 'Palæontologie Française' gives us full information of the distribution of the cretaceous species. There have been eleven species found in the subcretaceous beds, of which the six from the basin of Paris are small or of middling size, while all the five found in the South of France are very large: the fifteen species found in the *Craie chloritée* are all from the South of France, only one reaching as far north as the Loire; some of these are large, but they do not equal in average size the subcretaceous species from the same districts. None have been found in France in the upper chalk.

In Portugal I met with no *Nerinææ* in beds of the oolitic period; but these beds appear to have been deposited in deep seas; and moreover, my examination of them was too slight to found anything on this merely negative evidence. In the beds classed as subcretaceous the species of *Nerinæa* are numerous, and many reach a very large size. From the hippurite limestone, which is of the age of our chalk, and which I examined very thoroughly, I have three species, the largest of which is only of moderate size.

It thus appears that the period most favourable to the development of *Nerinææ* was that of the oolites in the North, and that of the greensand in the South of Europe. Comparing together the species found in different formations of any one country, we find the species of the older formation more numerous and on the average larger than those of the more modern formation.

But on comparing the *Nerinææ* found in the same formations in

different latitudes, we find that in each instance the average size of the species is larger in the south than in the north.

If it might be assumed that the species of *Nerinæa* reached a larger average size in warm than in cold climates, which is probable from what we know of the recent genera nearest to them in organization, two conclusions might be drawn from the preceding remarks: 1st, That in each of the epochs referred to, there was a similar difference between the climates of the North and South of Europe to that which now distinguishes them; 2ndly, That in each of the districts mentioned the temperature was gradually falling through the periods of the deposition of the oolitic and cretaceous series of beds. The first conclusion is in itself so probable that it will be readily accepted; the second must be substantiated by similar results drawn from the comparison of a large series of both animal and vegetable remains before it can be admitted.

In confirmation, however, of the latter conjecture, we find certain species of *Nerinæa* in the South of Europe in beds of a later period than those in which they are found in the North. Thus *N. Bruntrutana*, *N. grandis* (of Voltz, not of Goldfuss), and *N. cylindrica*, which near Lisbon are found in limestones of the subcretaceous period, occur in France and Germany either in the Portland oolite or the Kimmeridge clay; and *N. nobilis*, which occurs in a bed near Lisbon corresponding to our upper chalk, is found at Salzburg in the greensand. But I can find no contrary instance of a species occurring in the South in an older formation than in the North of Europe.

On some future occasion I shall show that species of other genera of Mollusca which are in the North of Europe confined to the oolitic formations lived on during the deposition of the cretaceous rocks of Portugal, and I will at the same time explain the grounds on which the classification of the Portuguese beds has been adopted. The facts seem to point out that the seas which covered Portugal during the cretaceous period had a temperature which in the latitude of England only existed during the deposition of the oolites; and this might be the case if the temperature of these parts of the globe was gradually falling. But I repeat that I am far from thinking these observations sufficient to prove so important a doctrine, and I only regard them as very slight evidence tending in that direction, and which may be confirmed or contradicted by further inquiries.

The following species of *Nerinæa* have been found in Portugal:—

Subgenus 1. NERINÆA.

N. nobilis, Goldf. t. 177. f. 9; *post*, t. 12. f. 1; common in the upper beds of the hippurite limestone near Lisbon.

*N. Archimedis**, D'Orb. T. Cret. 2. t. 158. f. 3, 4; in subcretaceous limestone in the cliffs at the Praia de Adrarga near Cintra.

* Perhaps *N. Archimedis* may be identical with *N. suprajurensis*, Voltz and Bronn, Jahrb. 1836, t. 6. f. 2 (not f. 3), and with *N. Defrancii*, Desh., but I have, in the doubt, adopted M. D'Orbigny's name, as the Portuguese shell agrees best with his figure.

N. cylindrica, Voltz and Bronn, Jahrb. 1836, t. 6. f. 16; in subcretaceous limestone at Sarjento-mór, six miles north of Coimbra, and in the cliffs at the Praia de Adrarga near Cintra.

N. gigantea, D'Hombres-Firmas, Mem.; D'Orb. Terr. Cret. 2. t.158. f. 1, 2; in subcretaceous limestone at Alenquer.

N. Titan, nobis, t. 12. f. 3; in subcretaceous limestone in the cliffs at the Praia de Maçams near Cintra.

Subgenus 3. TROCHALIA.

N. annulata, nobis, t. 13. f. 1; in subcretaceous limestone at Alenquer.

N. grandis, Voltz and Bronn, Jahrb. 1836, t. 6. f. 1; in subcretaceous limestone at Alenquer.

N. turbinata, nobis, t. 12. f. 2; in subcretaceous limestone between Sobral and Torres Vedras, and three miles south-west of Alenquer.

Subgenus 4. PTYGMATIS.

N. Eschwegii, nobis, t. 13. f. 2; in the upper beds of the hippurite limestone near Lisbon.

N. Olisiponensis, nobis, t. 13. f. 3; in the upper beds of the hippurite limestone near Lisbon, and in subcretaceous limestone at the Praia de Maçams near Cintra.

N. Bruntrutana, Thurmann; Voltz and Bronn, Jahrb. 1836, t. 6. f. 13 & 18; Goldf. t. 175. f. 5; in subcretaceous limestone at Alenquer.

N. Conimbrica, nobis, t. 13. f. 4; in subcretaceous limestone at Sarjento-mór, six miles north of Coimbra.

Description of the Species.

Subgenus 1. NERINÆA.

NERINÆA NOBILIS, Goldfuss, t. 177. f. 9.

Shell turreted, smooth, conical when young, cylindrical when old. Whorls numerous, very slightly convex, increasing slowly in size. Suture running along a faint depression. Mouth elongated, with a fold near the top of the outer lip and three folds on the columella. Columella solid, nearly equal in thickness to one-fourth of the diameter of the shell. Four simple folds in the interior, of which one on the outer lip projecting half across the whorl in a slope parallel to the base of the whorl; two on the columella, of which the upper one is the smaller, and nearly opposite to that on the outer lip; and one small fold on the top of the whorl sloping outwards.

Spiral angle irregular, about 15° in the young, hardly perceptible in the old shell. Sutural angle varying with the age from 100° to 110°. Basal angle* varying between 120° and 130°. Usual diameter of old shells from $\frac{3}{4}$ths to 1 inch, rarely $1\frac{1}{4}$ inch.

Very abundant in the upper beds of the hippurite limestone near Lisbon.

* I have used the term *basal angle* for the angle formed by the meeting of the side and base of the whorl. In this genus it furnishes a character by which many species otherwise similar externally may be distinguished.

I refer my shell to *N. nobilis* with some hesitation, because it never reaches the size of the specimen figured by Goldfuss from Salzburg, and it is only in its younger state that it has the *pupoidal* form of his species. Before reaching half the diameter of his specimen the Portuguese shells have usually become nearly or quite cylindrical; still I can find no distinctive characters upon which to found a new species. Most of the specimens found at Lisbon are internal casts, and neither in that state nor in the section can they be distinguished from *N. nodosa* of Voltz, with which I confounded them till specimens were found covered with the shell: the latter species has not been found at Lisbon. In the casts each whorl appears deeply divided into two rings; in the young shell, fig. 1 *b*, the lower ring is narrower and rounder than the upper; but in older shells, fig. 1 *c*, the two rings are nearly equal, and in this state the casts resemble those of *N. Borsoni*, which may perhaps be the same species.

Plate XII. fig. 1 *a*. Exterior of a young shell.
Fig. 1 *b*. Cast of a young shell.
Fig. 1 *c*. Cast of an old shell.
Fig. 1 *d*. Section of a shell nearly full-grown.

Nerinæa Titan, n. s.

Shell turreted, smooth, conical when young, cylindrical when old. Whorls very numerous, deeply concave in the middle; equal in height to one-third of the diameter of the shell; hardly increasing in size in the old shell. Suture in the middle of a broad high ridge. Mouth nearly square. Columella solid, occupying one-fifth of the diameter of the shell. Three folds in the interior, of which one on the middle of the outer lip has a broad base and sharp edge projecting but little; one on the columella slightly below the former projects thin and sharp beyond the middle of the whorl; one on the top of the whorl, sharp and smaller than the last, and curving outwards.

Sutural angle about 85° when young, 95° to 100° when old. Basal angle 105°. Spiral angle in young shells about 20°; when old the shell is so nearly cylindrical that in a fragment 5 inches long the diameter only increases one-eighth of an inch. Greatest diameter $2\frac{1}{4}$ inches.

Very abundant in the limestone beds of the subcretaceous series in the cliffs north of Cintra, especially at the Praia de Maçams, where a bed several feet thick is entirely formed of the debris of these shells.

This species resembles *N. gigantea*, which it fully equals in size, but it is readily distinguished by a flatter base to the whorl and squarer mouth, and by the two inner plaits projecting farther inwards; it is also closely related to *N. Goodhallii*.

Plate XII. fig. 3 *a*. Exterior.
Fig. 3 *b*. Section.

Subgenus 3. Trochalia.

Nerinæa annulata, n. s.

Shell conical, smooth, with projecting broad rings: spiral angle 25°, regular. Whorls numerous, deeply concave, one-fourth as long as they

are wide, increasing regularly. Suture in the middle of a rounded ridge, which is broader than the concavity of the whorl. Columella hollow, the umbilicus occupying about one-fourth of the diameter of the shell. Mouth subrhomboidal, with the outer lip indented. One fold in the interior, on the top of the whorl, curving outwards.

Sutural angle 85°. Basal angle 100°. Greatest diameter seen $1\frac{3}{4}$ inch.

Found in limestone near the base of the subcretaceous series at Alenquer.

Readily known by the regular annulations of the exterior, and by the single fold at the top of the nearly square interior of the whorls, in which it resembles *N. depressa*, *N. pyramidalis*, and *N. subpyramidalis*.

Plate XIII. fig. 1 *a*. Exterior.

Fig. 1 *b*. Section.

Nerinæa turbinata, n. s.

Shell conical, with a large umbilicus. Spire increasing regularly with an angle of about 35°; whorls about ten, concave in the middle and crossed by slightly oblique irregular lines of growth. Suture in the middle of a projecting ridge which is irregularly crenulated by the lines of growth. Mouth subrhomboidal, with a callosity inside the outer lip and a fold on the inner lip. Columella hollow, the umbilicus occupying one-third of the diameter of the shell. Two folds in the interior; one on the middle of the outer lip, the other a little below it on the columella. In the lower whorls the folds are nearly equal, and a section of the space left is a rude representation of an hour-glass; in the upper whorls the outer fold becomes much larger than its fellow.

Sutural angle about 90°. Basal angle about 95°. Total length $1\frac{3}{4}$ inch. Diameter $\frac{3}{4}$ of an inch.

Found in limestone near the base of the subcretaceous series three miles south-west of Alenquer, and between Torres Vedras and Sobral.

In external form and markings this shell so exactly resembles *Trochus Astierianus* of D'Orbigny, Terr. Cret. pl. 176. f. 16, 17, that they might easily be confounded; but the latter species is figured without an umbilicus, and is described as not umbilicated (p. 182).

Our species is allied to *N. Renauxiana*, D'Orb., by its hollow columella, and it resembles the young state of that species in its spiral angle; but it has a fold less on the columella. About twenty specimens have been seen, all so nearly of the same size that they may be presumed to be full-grown shells.

Plate XII. fig. 2 *a*. Exterior.

Fig. 2 *b*. Section of the interior of another specimen.

Subgenus 4. Ptygmatis.

Nerinæa Eschwegii, n. s.

Shell turreted, cylindrical, smooth. Whorls numerous, nearly equal, convex, equal in height to half the diameter of the shell. Suture running in a marked depression. Columella solid, small.

Four folds in the interior reducing the hollow of the whorl to a very narrow complicated passage; viz. two folds on the columella, of which the upper is thin and very small, the lower larger, with a wide base which rapidly decreases to a thin edge and is again thickened at the extremity; one large fold on the top of the whorl with a wide base, curving outwards and thickened at its extreme edge, and one fold on the outer lip thickened at its edge. Besides these four folds there is a callosity at the top of the whorl near the outer lip and another at the base of the whorl.

Sutural angle between 95° and 100°. Basal angle 110°.

Rare in the hippurite limestone near Lisbon.

Closely allied to *N. Olisiponensis*, this species may be recognised by its cylindrical form, deep sutural depression, and by a more complicated internal structure.

I have named this shell after the Baron d'Eschwege, the first geologist who seriously attempted to work out the series of Portuguese formations, and to whose kindness I have been largely indebted for assistance and information during my visits to Portugal.

Plate XIII. fig. 2 *a*. Exterior.

Fig. 2 *b*. Section of the same specimen.

Nerinæa Olisiponensis, n. s.

Shell turreted, slightly conical, smooth; spire increasing slowly; spiral angle 10° in the young, 5° in the old shell. Whorls very numerous, smooth, with straight sides and nearly flat below, separated by a well-marked suture. Columella solid, small. Four folds in the interior, which reduce the hollow to very narrow dimensions of a most complicated form, viz. two folds on the columella, of which the upper is small and sharp, the lower prominent and thickened at the extremity; one strong sharp fold on the outer lip, and one long thin fold on the top projecting outwards in a curve. Besides these there is a faint ridge along the top of the whorl close to the outer lip.

Sutural angle between 90° and 95°. Basal angle about 100°. Greatest diameter observed 1 inch.

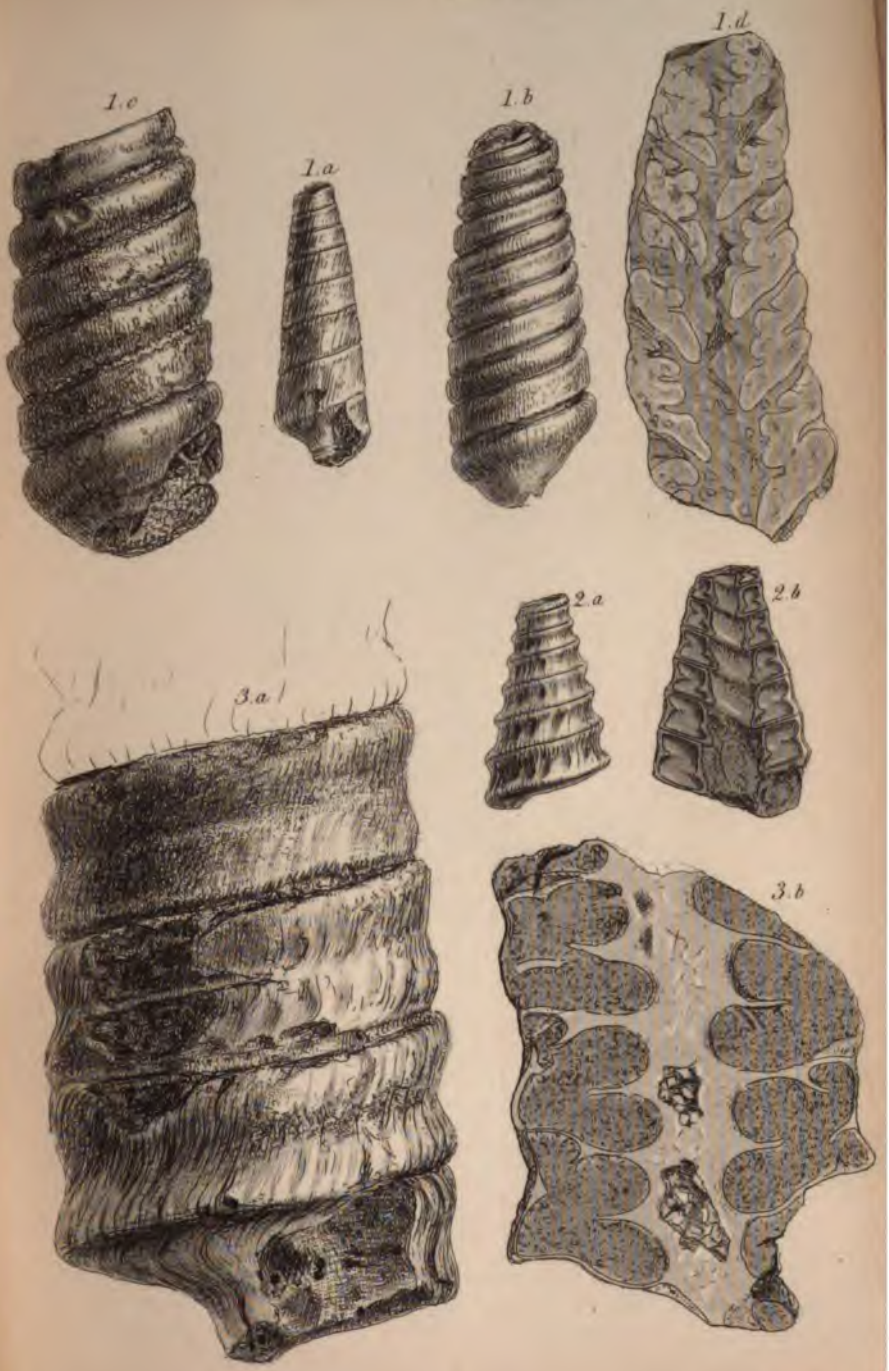
Found in the hippurite limestone at Lisbon and in the subcretaceous limestone at the Praia de Maçams north of Cintra.

Plate XIII. fig. 3 *a*. Exterior.

Fig. 3 *b*. Section.

Nerinæa Conimbrica, n. s.

Shell turreted, slightly tapering when young, nearly cylindrical when old, almost smooth. Whorls very numerous, increasing slowly in size; very slightly convex, faintly marked with oblique lines of growth. Suture marked by two delicately impressed lines. Mouth subrhomboidal, with one strong fold on the outer lip and two long curved folds on the columella. Columella solid, small. Four folds in the interior, which reduce the hollow to a narrow complicated passage; of these, two folds are on the columella, the lower one longer than the other, and both thickest near the extremity; one large fold on the outer lip, and one long thin fold on the top curving outwards.



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ASTOR, LENOX AND
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1.a

1.b

2.a

2.b

3.a

3.b

4.a

4.b

4.c

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Sutural angle about 95°. Basal angle 100°. Greatest diameter ¾ of an inch.

Found in limestone of the subcretaceous series at the village of Sarjento-mór, six miles north of Coimbra.

PLATE XIII. fig. 4 *a*. Exterior.

Fig. 4 *b*. Internal cast.

Fig. 4 *c*. Section.

EXPLANATION OF THE PLATES.

PLATE XII.

Fig. 1. Nerinæa nobilis.
Fig 2. Nerinæa turbinata.
Fig. 3. Nerinæa Titan.

PLATE XIII.

Fig. 1. Nerinæa annulata.
Fig. 2. Nerinæa Eschwegii.
Fig. 3. Nerinæa Olisiponensis.
Fig. 4. Nerinæa Conimbrica.

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2. *Section of the* LOWER COAL-MEASURES *of the* SYDNEY COAL-FIELD, *in the* ISLAND OF CAPE BRETON. By RICHARD BROWN, Esq.

[Communicated by the Secretary.]

THE coal-measures of Nova Scotia Proper have been carefully examined and described by Sir Charles Lyell. Mr. Logan has also published a "Section of the Nova Scotia Coal-Measures, as developed at the Joggins in the Bay of Fundy," which appears to have attracted much attention; but the Cape Breton coal-fields, in every point of view the most important in British America, appear to have been almost wholly neglected by geologists. I have been for some years engaged in collecting materials for a description of the Sydney coal-field, but seeing no immediate prospect, amidst the engrossing duties of an arduous profession, of completing such an extensive work, I have concluded to submit to the Society a detailed section of the lower part of the productive coal-measures, as developed on the shores of Sydney Harbour, under the impression that it will furnish many valuable facts and data calculated in an eminent degree to elucidate the origin of the coal beds, and at the same time to assist geologists in instituting a comparison with the Bay of Fundy section, from which it will be found to differ in at least one very important feature, to which I shall refer more particularly in the sequel.

This coal formation, as has been already stated in vol. i. p. 23 of this Journal, consists of the following group of strata :—

4. The productive coal-measures.
3. A thick deposit of sandstone.
2. Limestones and shales, occasionally containing beds of gypsum.
1. A coarse conglomerate.

The lowest member of this group (1), the representative probably of the old red sandstone of Europe, crops out from beneath the carboniferous limestone at the head of the north-west branch of Sydney Harbour, where it consists of thick beds of conglomerate alternating

with red shale. The conglomerate is chiefly composed of fragments of red granite and quartz pebbles, cemented together in a base of ferruginous red clay. Its thickness has not been ascertained.

The next member of the group (2) consists of alternating beds of limestone, red and brown shales, and friable micaceous sandstones. No beds of gypsum are visible in this section; it is only in the neighbourhood of the protruded masses of granite and trap that gypsum is met with. The total thickness of this series is 820 feet. Fossils are rare and of few species; the most common are *Producta Lyelli*, *P. spinosa*, *P. Martini*, *P. Scotica*, *Spirifer glaber*; and a few undetermined scales of fishes, in one of the upper limestone beds. Some of the shales are finely laminated and rippled. Stigmariæ, apparently drifted, as no rootlets are attached to them, occur in a bed of arenaceous shale in the higher part of the section.

The sandstone deposit (3), which is analogous in position to the millstone grit of the English coal-fields, is 1800 feet in thickness. The lower beds are coarse and pebbly; the upper, fine-grained, and often flaggy, containing impressions of Sigillariæ, Calamites, and Lepidodendra. A few thin beds of grey shale are interstratified with the sandstones at wide intervals.

The productive coal-measures (4) cover an area of 250 square miles, but owing to several extensive dislocations it is impossible to ascertain their total thickness with any degree of accuracy; from the best information in my possession I conclude that it exceeds 10,000 feet. We have one continuous section on the north shore of Boulardrie Island 5400 feet in thickness, and in the middle portion of the field, several detached sections varying from 1000 to 2000 feet in thickness, whose exact relative positions have not yet been determined, although it is quite clear that they are higher up in the formation than the *highest* beds of the Boulardrie section. These points can only be ascertained by a careful survey of the whole district; I therefore propose, as I said before, to confine my observations at present to the small portion exhibited in the cliff on the north-west shore of Sydney Harbour.

The coal-measures commence at Stubbord's Point, where they repose conformably upon the millstone grit, and terminate at Cranberry Head on the sea-shore; the total length of the section being 5000 yards, and the thickness from actual measurements, taken at right angles to the plane of stratification, 1860 feet. The dip is north 60° E. at an angle of 7°.

In the following table the beds are placed in their natural order, No. 367 being the highest bed at Cranberry Head, and No. 1 the lowest, in contact with the millstone grit at Stubbord's Point.

Section of the Coal-Measures on the north-west shore of Sydney Harbour, in the descending order.

No.		ft.	in.
367.	Slaty sandstone	10	0
366.	Soft blue argillaceous shale	0	6
365.	Argillaceous shale containing a few small nodules of ironstone near the bottom (plants)	4	0
364.	Argillaceous shale (plants)	2	0

No.		ft.	in.
363.	Coal	0	1
362.	Underclay (Stigmaria)	2	0
361.	Arenaceous shale (plants)	3	0
360.	Coal (Cranberry Head, top seam)	3	8
359.	Underclay (Stigmaria)	0	10
358.	Hard arenaceous shale (Stigmaria)	4	8
357.	Arenaceous shale (plants)	3	0
356.	Coal (not persistent)	0	0½
355.	Arenaceous shale (plants, erect trees and Stigmaria)	7	0
354.	Soft blue clay	0	2
353.	Coal ft. 0 in. 2; Soft clay 0 2; Coal 0 8 (Cranberry Head, bottom seam)	1	0
352.	Underclay (Stigmaria)	0	7
351.	Argillaceous shale with thin carbonaceous layers (Stigmaria)	0	10
350.	Hard arenaceous shale (Stigmaria)	2	6
349.	Strong slaty sandstone (ripple-marks)	2	8
348.	Slaty, waving sandstone	4	6
347.	Sandstone and argillaceous shale, mixed	2	0
346.	Argillaceous shale	0	6
345.	Arenaceous shale alternating with sandstones in layers of 2 to 12 inches thick (plants and erect trees)	8	0
344.	Argillaceous shale (plants and erect trees)	11	0
343.	Alternating laminæ of shale and carbonaceous matter	5	6
342.	Argillaceous shale (ferruginous concretions)	7	0
341.	Arenaceous shale	2	0
340.	Arenaceous shale, passes into soft sandstone	4	0
339.	Mixed sandstone and shale	7	0
338.	Soft clay	0	2
337.	Purple argillaceous shale	1	6
336.	Argillaceous shale	1	0
335.	Purple argillaceous shale	1	4
334.	Greenish arenaceous shale	5	0
333.	Purple argillaceous shale	0	9
332.	Sandstone in thin laminæ	8	0
331.	Red argillaceous shale with thin green layers	8	6
330.	Arenaceous shale	7	0
329.	Red argillaceous shale	2	9
328.	Arenaceous shale	2	10
327.	Red argillaceous shale	1	4
326.	Greenish laminated sandstone	14	0
325.	Red argillaceous shale containing 6 inches of sandstone	1	9
324.	Slaty sandstone	8	0
323.	Brown argillaceous shale	0	8
322.	Arenaceous shale with four layers of red argillaceous shale at intervals of 5 feet	25	8
321.	Slaty sandstone with two thin layers of red shale	9	7
320.	Intermingled brown, grey, and red arenaceous shales	9	0
319.	Red argillaceous shale	9	0
318.	Arenaceous shale	3	0
317.	Sandstone	10	0
316.	Alternating layers of shale and sandstone 1 to 4 inches each	3	0
315.	Sandstone	6	0
314.	Ferruginous arenaceous shale	9	4
313.	Argillaceous shale containing thin carbonaceous layers	0	9
312.	Arenaceous shale	4	8
311.	Soft crumbling sandstone	2	0
310.	Strong sandstone (plants)	13	0
309.	Argillaceous shale	1	0
308.	Mixed argillaceous shale and impure coal	0	6

No.		ft.	in.
307.	Underclay (Stigmaria)	2	0
306.	Mixed argillaceous shale and coal	1	0
305.	Underclay (Stigmaria)	6	0
304.	Argillaceous shale (plants)	2	0
303.	Argillaceous shale containing small nodules of ironstone (erect trees)	3	0
302.	Soft argillaceous shale	2	6
301.	Coal 0 2; Soft shale 0 8; Coal 0 3	1	1
300.	Underclay (Stigmaria)	1	8
299.	Sandstone (erect Calamites)	7	10
298.	Argillaceous shale (plants)	4	2
297.	Mixed layers, argillaceous and carbonaceous shale	0	7
296.	Argillaceous shale containing ironstone nodules (plants)	3	0
295.	Coal (Lloyd's Cove seam)	5	0
294.	Underclay (Stigmaria)	3	4
293.	Laminated arenaceous shales	10	6
292.	Laminated sandstone	4	10
291.	Laminated arenaceous shales	5	6
290.	Strong slaty sandstone	2	4
289.	Greenish arenaceous shale	8	0
288.	Alternating slaty sandstones and arenaceous shales	19	0
287.	Unseen beds, horizontal distance 480 yards*	144	0
286.	Argillaceous shale	2	0
285.	Traces of a thin coal not exceeding	0	3
284.	Underclay (Stigmaria)	4	0
283.	Arenaceous shale	5	6
282.	Strong sandstone (plants)	41	0
281.	Coal 0 7; Soft shale 0 5; Coal 0 4	1	4
280.	Soft clay	0	1
279.	Underclay (Stigmaria)	3	0
278.	Argillaceous shale	3	0
277.	Coal and carbonaceous shale	0	5
276.	Underclay (Stigmaria)	4	4
275.	Argillaceous shale containing nodules of ironstone	6	8
274.	Arenaceous shale (Stigmaria)	5	1
273.	Arenaceous shale, passes into sandstone	13	0
272.	Strong sandstone (plants)	31	0
271.	Argillaceous shale (plants)	4	2
270.	Argillaceous shale containing nodules of ironstone	9	4
269.	Coal and carbonaceous shale	0	9
268.	Underclay (Stigmaria)	4	10
267.	Strong sandstone (plants)	14	0
266.	Arenaceous and argillaceous shales (plants)	6	2
265.	Argillaceous shale	1	1
264.	Coal 1 4; Soft shale 0 4; Coal and carbonaceous shale 0 5	2	1

* These beds are concealed by the beach gravel in the direct line of our section, but their outcrop can be distinctly traced on the sea-shore on the opposite side of the promontory of Cranberry Head: they consist of alternating shales and sandstones; the latter run out in long ledges, but the former have been washed away by the surf, and can only be seen at low-water of spring tides.

No.		ft.	in.
263.	Underclay (Stigmaria)	0	5
262.	Arenaceous shale containing nodules of ironstone	2	0
261.	Coal	0	4
260.	Underclay (Stigmaria)	5	0
259.	Arenaceous shale	1	9
258.	Argillaceous shale	7	2
257.	Laminated arenaceous shale	3	6
256.	Argillaceous shale	4	1
255.	Coal	0	3
254.	Underclay (Stigmaria)	1	11
253.	Arenaceous shale	12	6
252.	Reddish brown argillaceous shale	5	0
251.	Grey and red argillaceous shale	12	0
250.	Strong sandstone	10	4
249.	Purple mottled argillaceous shale	10	8
248.	Green arenaceous shale	11	0
247.	Arenaceous shale	2	0
246.	Argillaceous shale	11	3
245.	Sandstone	47	0
244.	Argillaceous shale	0	9
243.	Black bituminous shale (fish-scales, coprolites, Cypris)	0	2
242.	Calcareo-bituminous shale (fish-scales, teeth, Cypris)	0	2
241.	Carbonaceous shale	0	1
240.	Underclay (Stigmaria)	2	0
239.	Laminated sandstone (plants)	0	11
238.	Underclay (Stigmaria)	2	0
237.	Laminated grey sandstone (ripple-marks)	0	6
236.	Argillaceous shale containing nodules of ironstone	0	1
235.	Crumbling arenaceous shale containing large masses of concretionary sandstone	3	2
234.	Laminated grey sandstone (Fucoids)	1	2
233.	Arenaceous shale	0	1
232.	Laminated grey sandstone (Fucoids)	1	4
231.	Mixed sandstone and crumbling arenaceous shale containing large concretionary masses of sandstone	2	4
230.	Arenaceous shale	2	6
229.	Slaty sandstone	1	2
228.	Arenaceous shale	7	0
227.	Black bituminous shale (fish-scales, teeth, coprolites and exuviæ of Cypris)	1	6
226.	Soft argillaceous shale	0	2
225.	Bituminous shale (fish-scales, coprolites, Cypris and Modiola)	1	6
224.	Green arenaceous shale	1	7
223.	Mixed sandstone and shale	1	6
222.	Argillaceous shale	0	2
221.	Arenaceous shale containing a few nodules of ironstone	4	4
220.	Strong sandstone	1	0
219.	Argillaceous shale	2	10
218.	Coal	0	4
217.	Underclay (Stigmaria)	4	0
216.	Argillaceous shale	5	10
215.	Arenaceous shale	4	8
214.	Red argillaceous shale, replaced by sandstone higher up in the cliff (Fucoids and rain-drops in sandstone)	5	0
213.	Green arenaceous shale	8	2
212.	Red argillaceous shale	1	6
211.	Arenaceous shale (Fucoids, ripple-marks)	7	2
210.	Strong sandstone	7	8
209.	Argillaceous shale	1	0

No.		ft.	in.
208.	Waving alternating sandstones and arenaceous shales	12	0
207.	Strong sandstone	21	0
206.	Argillaceous shale	0	10
205.	Arenaceous shale	11	4
204.	Laminated sandstone	12	8
203.	Arenaceous shale (plants)	6	2
202.	Hard band of carbonaceous shale (Modiola)	0	1½
201.	Argillaceous shale	6	0
200.	Bluish bituminous shale (Cypris, Modiola, plants)	6	6
199.	Black bituminous shale (Cypris, Modiola, fish-scales, teeth and spines, coprolites)	0	7
198.	Soft bluish-white clay	0	1
197.	Laminated slightly bituminous shale (Modiola)	2	7
196.	Slaty sandstone (plants, a bivalve shell)	0	3
195.	Arenaceous shale	2	0
194.	Argillaceous shale	2	9
193.	Carbonaceous shale	0	2
192.	Argillaceous shale	1	9
191.	Mixed sandstones and arenaceous shales	19	0
190.	Strong sandstone	24	0
189.	Argillaceous shale (erect trees, plants, Stigmaria), varies in thickness from 2 to 6 feet	4	0
188.	Coal (the main coal seam)	6	0
187.	Underclay (Stigmaria)	8	0
186.	Argillaceous shale	1	3
185.	Arenaceous shale (erect trees, plants, Stigmaria)	5	0
184.	Soft blue clay	0	0½
183.	Arenaceous shale (erect trees, plants, Stigmaria)	4	0
182.	Argillaceous shale mixed with coal	0	3
181.	Underclay (Stigmaria)	3	2
180.	Carbonaceous matter	0	0½
179.	Underclay (Stigmaria)	2	4
178.	Strong sandstone	8	0
177.	Arenaceous shale	2	2
176.	Argillaceous shale (plants)	1	10
175.	Arenaceous shale (erect trees)	4	0
174.	Argillaceous shale	2	7
173.	Argillaceous shale containing layers of coal	0	5
172.	Coal (Calamites in this seam)	0	9
171.	Underclay (Stigmaria)	1	0
170.	Arenaceous shale (plants)	6	3
169.	Argillaceous shale containing layers of coal	0	2
168.	Underclay (Stigmaria)	4	8
167.	Coal	0	4
166.	Underclay (Stigmaria)	2	3
165.	Soft blue clay	0	2
164.	Argillaceous shale	8	11
163.	Sandstone (erect trees)	7	0
162.	Argillaceous shale	1	3
161.	Coal mixed with argillaceous shale	0	3
160.	Underclay (Stigmaria)	1	2
159.	Sandstone	4	10
158.	Arenaceous shale containing concretions of sandstone	6	1
157.	Arenaceous shale	4	9
156.	Coarse sparry limestone (fish-scales, teeth, spines, fins, bones, and coprolites)	0	7
155.	Hard nodular arenaceous shale	1	0
154.	Limestone (scales, teeth, &c. of fishes)	0	2
153.	Argillaceous shale	0	3
152.	Limestone (scales, teeth, &c. of fishes)	0	4

No.		ft.	in.
151.	Green arenaceous shale	1	2
150.	Red argillaceous shale with mottled green layers	8	4
149.	Mixed red and grey argillaceous shales	3	0
148.	Coarse brown pebbly sandstone	0	7
147.	Red argillaceous shale	0	4
146.	Coarse brown pebbly sandstone	0	3
145.	Brown argillaceous shale	0	2
144.	Mixed sandstone and shale	0	6
143.	Strong brown conglomerate	0	8
142.	Mixed red and grey argillaceous shale, green mottles	13	2
141.	Green laminated sandstone	3	11
140.	Mixed argillaceous and bituminous shales	0	2
139.	Black slaty limestone	0	2
138.	Coarse grey limestone (fish-scales, coprolites)	0	7
137.	Brown and green mottled argillaceous shales	6	0
136.	Strong green sandstone	2	11
135.	Red argillaceous shale	3	0
134.	Arenaceous shale	1	10
133.	Argillaceous shale	2	0
132.	Deep red argillaceous shale	10	3
131.	Arenaceous shale	14	0
130.	Sandstone	9	0
129.	Argillaceous shale, thickness varies from 1 to 12 inches	0	6
128.	Sandstone (plants)	8	6
127.	Argillaceous shale (plants)	0	11
126.	Coal (in. 2) / Carbonaceous shale (in. 1) / Coal (in. 3) / Carbonaceous shale (in. 2) / Coal (in. 3) (Quarry seam)	0	11
125.	Underclay (Stigmaria)	3	0
124.	Argillaceous shale, a layer of ironstone of 1 in., 5 ft. from top	8	8
123.	Red and grey mottled argillaceous shale	26	0
122.	Arenaceous shale	9	2
121.	Finely laminated arenaceous shale	3	6
120.	Ironstone	0	1
119.	Arenaceous shales (Fucoids, plants, erect trees)	9	0
118.	Grey and red mottled arenaceous shale	13	3
117.	Argillaceous shale	3	9
116.	Carbonaceous shale	0	4
115.	Coal	0	4
114.	Underclay (Stigmaria)	5	6
113.	Alternating layers of sandstone and arenaceous shales containing a few thin layers of ironstone	11	9
112.	Alternating sandstones and shales (plants)	12	0
111.	Argillaceous shale containing ironstone nodules	3	9
110.	Laminated sandstone	10	4
109.	Arenaceous shale (plants)	2	8
108.	Coal (in. 5) / Calcareo-carbonaceous shale (in. 2) / Coal (in. 1) (Cypris, Spirorbis in shale)	0	8
107.	Underclay (Stigmaria)	4	0
106.	Alternating sandstones and arenaceous shales	8	2
105.	Strong waving sandstone	10	0
104.	Argillaceous shale	1	2
103.	Argillaceous and carbonaceous shales	0	6
102.	Bituminous shale (plants, Cypris, Spirorbis, Modiola)	3	0
101.	Coal	1	3

No.		ft.	in.
100.	Underclay (Stigmaria)	3	1
99.	Strong sandstone	18	0
98.	Red, brown and grey argillaceous shales	32	0
97.	Green sandstone	1	4
96.	Argillaceous shale containing ironstone nodules	2	0
95.	Laminated sandstone	3	3
94.	Red argillaceous shale	2	10
93.	Soft white clay	0	2
92.	Pure white limestone (*Microconchus carbonarius*)	0	2
91.	Greenish arenaceous shale	4	2
90.	Argillaceous shale	0	10
89.	Arenaceous shale	8	6
88.	Slaty micaceous sandstones with layers of shale (plants, erect Calamites)	10	6
87.	Arenaceous shale	4	0
86.	Argillaceous shale	3	6
85.	Arenaceous shale (erect trees, Stigmaria)	5	6
84.	Laminated carbonaceous shale	0	6
83.	Underclay (Stigmaria)	0	8
82.	Alternating layers of bituminous and arenaceous shale with thin plies of coal	5	9
81.	Argillaceous and arenaceous shale containing layers of sandstone (Fucoids in sandstone, Stigmaria in shale)	7	0
80.	Arenaceous and bituminous shale in layers of about 1 inch thick (Modiola, Cypris)	3	9
79.	Bituminous shale (Modiola, Cypris, fish-scales, teeth and spines, comminuted shells)	2	10
78.	Coal (Indian Cove seam)	4	8
77.	Underclay (Stigmaria)	2	3
76.	Argillaceous and arenaceous shales containing a few nodules of ironstone	15	9
75.	Red and brown argillaceous shales	11	0
74.	Arenaceous shale	6	6
73.	Argillaceous shale	4	0
72.	Arenaceous shale	5	3
71.	Argillaceous shale	3	3
70.	Sandstone containing nodules of ironstone	4	0
69.	Arenaceous shale	3	3
68.	Bituminous shale (comminuted shells)	1	5
67.	Bituminous limestone, clay parting in the middle	1	3
66.	Arenaceous shale containing a layer of ironstone 1 inch	1	0
65.	Argillaceous shale with carbonaceous layers	0	6
64.	Argillaceous shale (plants)	2	4
63.	Coal	0	11
62.	Underclay (Stigmaria, plants)	3	1
61.	Arenaceous shale containing ironstone nodules (plants)	16	0
60.	Argillaceous shale containing ironstone nodules (plants)	2	10
59.	Coal	1	4
58.	Underclay (Stigmaria)	5	10
57.	Sandstone (plants)	13	0
56.	Argillaceous shale (Stigmaria)	2	0
55.	Coal	0	7
54.	Underclay (Stigmaria, plants)	8	11
53.	Coal	0	2
52.	Underclay (Stigmaria and nodules of ironstone, erect trees)	4	8
51.	Argillaceous shale (erect trees)	7	10
50.	Coal	0	2
49.	Underclay (Stigmaria)	6	0
48.	Arenaceous shale	3	0
47.	Mottled brown and green arenaceous shale	4	4

No.		ft.	in.
46.	Deep red argillaceous shale, mottled green	19	0
45.	Arenaceous shale	5	2
44.	Sandstone	4	10
43.	Alternating layers of sandstone and arenaceous shale	4	2
42.	Laminated sandstone	8	8
41.	Strong sandstone	8	4
40.	Arenaceous shale containing nodules of ironstone	6	8
39.	Argillaceous shale	2	11
38.	Bituminous shale	1	8
37.	Coal 1 in.; Argillaceous shale 3 in.; Coal 2 in.; Argillaceous shale 2 in.; Coal 2 in.	0	10
36.	Underclay (Stigmaria and nodules of ironstone)	1	0
35.	Coal	0	0½
34.	Underclay (Stigmaria)	0	8
33.	Soft blue clay	0	2
32.	Coal 1 ft. 2 in.; Carbonaceous shale 0 ft. 2 in.; Soft blue clay 0 ft. 2 in.; Coal 1 ft. 3 in.; Carbonaceous shale 0 ft. 3 in.; Coal 0 ft. 2 in. (Stony seam)	3	2
31.	Underclay (Stigmaria)	1	0
30.	Carbonaceous shale	0	3
29.	Calcareous shale (fish-scales and coprolites)	0	2
28.	Soft argillaceous shale with a few thin layers of carbonaceous matter	0	6
27.	Coal 2 in.; Argillaceous shale 1 in.; Coal 1 in.; Carbonaceous shale 6 in.; Coal 2 in. (Shelly seam)	1	0
26.	Bluish black limestone (fish-scales, coprolites, Cypris)	0	6
25.	Hard arenaceous shale	7	0
24.	Laminated waving sandstone	7	8
23.	Argillaceous shale	3	6
22.	Greenish grey argillaceous shale	23	6
21.	Sandstone (Stigmaria, Fucoids, ironstone nodules)	16	0
20.	Argillaceous shale (plants)	0	9
19.	Sandstone (plants)	6	3
18.	Coal	1	0
17.	Underclay (Stigmaria)	1	9
16.	Argillaceous shale with some carbonaceous layers	1	0
15.	Coal	0	1
14.	Underclay (Stigmaria)	3	4
13.	Argillaceous shale	3	0
12.	Coal	0	0½
11.	Underclay (Stigmaria)	5	4
10.	Arenaceous shale	2	8
9.	Argillaceous shale	14	2
8.	Coal	0	0½
7.	Underclay (Stigmaria)	4	10
6.	Argillaceous shale, mere traces of coal at bottom	9	0
5.	Underclay (Stigmaria)	3	0
4.	Laminated arenaceous shale	4	10

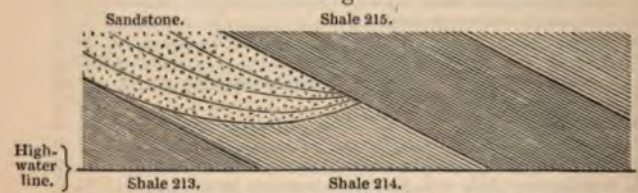
No.		ft.	in.
3.	Laminated sandstone	5	4
2.	Laminated arenaceous shale	3	0
1.	Laminated sandstone	11	0
	The highest bed of the millstone grit, a flaggy sandstone.		
	Total thickness of coal-measures...	1860	0

Analysis of the preceding Section.

	ft.	in.
Arenaceous and argillaceous shales ...	1127	3
Underclays	99	6
Sandstones	562	0
Coal	37	0
Bituminous shales	26	5
Carbonaceous shales	3	3
Limestones	3	11
Conglomerate	0	8
	1860	0

From this analysis it appears that the argillaceous and arenaceous shales occupy about two-thirds of the whole section; they are generally of a grey or bluish grey colour, but occasionally red, purple, or brown, as specified in the section. Their composition is variable, passing from soft unctuous clays, through every conceivable grade, into arenaceous beds so highly charged with siliceous matter, as to be with difficulty distinguished from fine-grained sandstones. They are generally laminated, but there are many beds, some of great thickness, which present no traces of lamination; these disintegrate rapidly when exposed to the air, and might more properly perhaps be designated marls. Viewed at some distance from the water the parallelism and persistence of the shale beds appear to be perfect; it is only by a close examination that we occasionally discover a bed of shale replaced by sandstone, as in the annexed cut, where the bed of red

Fig. 1.



shale, No. 214, terminates at the height of eight feet above high-water line, and is replaced by hard laminated sandstone, which overlaps the edge of the shale. The underside of the sandstone, in contact with the subjacent shale No. 213, presents markings of fucoids, which cannot be observed upon the underside of the red shale, showing, that in the interval between the deposition of the red shale and the sandstone unconformably upon its edges, a layer of sea-weeds had been spread over the uncovered portion of the surface of the shale No. 213.

The red shales are very irregular in thickness; thin beds of twelve or fifteen inches sometimes increase to three or four feet in depth

within a space of thirty feet. In some instances a bed of shale of a deep red colour at the outcrop passes gradually through all the shades of red, purple, brown and grey, until, at the foot of the cliff, it cannot be distinguished from common grey shale; and in others, as represented in the cut, a bed three feet thick at the outcrop thins out altogether before it reaches high-water mark.

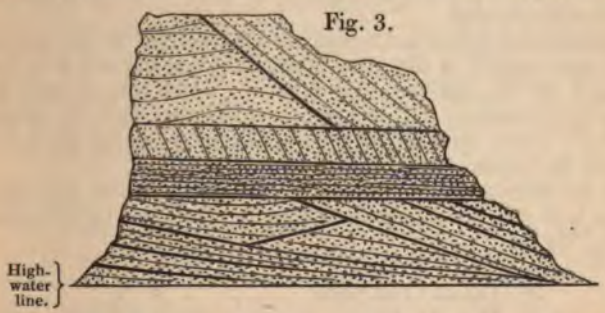
Fig. 2.

1. Grey shale. 2. Red shale. 3. High-water line.

Argillaceous ironstone is found in small detached nodules, rarely in continuous layers, in many of the shales, but never in sufficient quantity for working profitably.

The total thickness of the sandstone beds is 562 feet; they are of a greyish white colour, sometimes tinged brown or green. The thick beds are generally coarse; those numbered 272, 282 and 310 contain rounded pebbles of white quartz of all sizes up to one inch in diameter. False stratification is very common in the thick beds; one of the most remarkable examples is shown in fig. 3, which is a

Fig. 3.



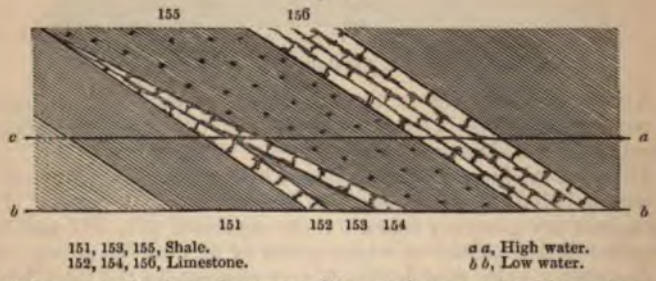
sketch of an outlying mass separated from bed No. 272; its height is 9 feet. Many of the sandstones are micaceous and flaggy; some (Nos. 42, 292, 293, 294 and 332) so finely laminated and regular in their bedding, that from twenty to thirty distinct layers can be counted in one inch of depth.

The bituminous shales are not numerous, their united thickness being only 26 feet; they are of a black colour, and all more or less inflammable; those numbered 225 and 227 may be designated impure Cannel coals, being very compact, possessing a conchoidal fracture, and burning for a short time with a bright yellow flame. The remainder are soft and laminated. They are all highly fossiliferous, as will be noticed in the sequel.

The carbonaceous shales, composed of argillaceous mud charged with decaying vegetable matter, occur interstratified with thin layers of coal.

The beds of limestone are rare, and with the exception of the two-inch layer, No. 92, very coarse and impure, being charged with carbon, bitumen, or siliceous matter. The persistence and uniform thickness of all the limestone beds, except those numbered 152 and 154, are very remarkable. The two last are separated at low-water mark by a three-inch layer of shale; at high-water mark they merge into one bed, and at eight feet higher up thin out, as represented in the annexed cut.

Fig. 4.



Only one bed of conglomerate (No. 143) occurs in this section; it is composed of small quartz and granite pebbles united in a base of brown ferruginous clay.

The sandstones, shales and limestones are traversed by two sets of joints at right angles to the plane of stratification, the course of one set being S. 80° E., and the other S. 5° W., which consequently divide the beds vertically into blocks of a rectangular form, as nearly as may be. These joints are of great service in quarrying the sandstone beds for building purposes.

There are thirty-one seams of coal in this section, whose aggregate thickness is 37 feet; four only are of sufficient thickness to be worked profitably, viz.—

Nos.		ft.	in.
78.	Indian Cove Seam	4	8
188.	Main Coal	6	0
295.	Lloyd's Cove Seam	5	0
360.	Cranberry Head Top Seam ...	3	8

The relative positions of the several seams may be best understood by referring to the section. The coal is in every instance bituminous; the quality of that obtained from the four seams above-named is unexceptionable *.

All the coal-seams save one (No. 27), which will shortly be noticed, and indeed almost every layer of carbonaceous shale, lie upon under-

* About 80,000 tons of coal are raised annually from the Main Seam, of which 30,000 tons are consumed in Nova Scotia, the remainder being chiefly shipped to Newfoundland and the United States.

clays. The upper layers of the underclays immediately in contact with the coal are argillaceous, forming sometimes good fireclays: from six to twelve inches below the coal they contain variable proportions of siliceous matter, being in a few instances scarcely distinguishable from sandstones.

Stigmariæ are found in all the underclays, in several of the shale roofs of the coal-seams, and in some beds of shale (Nos. 81, 238 and 274) which constitute neither floors nor roofs. In the first case they are very numerous, and of several species, although *S. ficoides* is the most common. In the second they are not so plentiful, occurring probably only in connexion with the erect trees, of which they are the roots. In the last case they are very rare, and where they are not united to erect trees, most probably have been drifted, carrying with them a portion of their long rootlets, of which there is one very decided example in another part of the Sydney coal-field *.

It does not appear that the thickest underclays, containing the greatest number of Stigmariæ, are overlaid by proportionably thick seams of coal; the reverse is often the fact: for instance, the three lowest seams in our section (Nos. 8, 12 and 15), none of which exceed 1 inch, lie upon underclays 4 ft. 10 in., 5 ft. 4 in. and 3 ft. 4 in. in thickness, respectively, while on the other hand, the seams Nos. 78 and 295, the one 4 ft. 8 in. and the other 5 ft., rest upon underclays by no means rich in Stigmariæ, only 2 ft. 3 in. and 3 ft. 4 in. in thickness. In the two latter cases, probably, the increase of Stigmariæ was interrupted by a subsidence which produced the conditions required for the growth or accumulation of the vegetable mass from which the coal beds were formed. In the former instances, similar conditions having been obtained and the growth of the vegetable mass just commenced, a subsidence took place almost immediately, which at once put a stop to the increase of the material required to form coal. If the strata had been suffered to remain in a state of rest for a longer period, the bed of coal No. 8, which is only half an inch, might have attained a thickness equal or superior to any in the section.

As before mentioned, the seam of coal No. 27 forms an exception to the general rule; it lies upon a coarse limestone 6 inches thick, which rests upon a hard arenaceous shale, not unlike some of the more sandy underclays; but it neither crumbles on exposure to the weather, nor does it contain the slightest trace of a Stigmaria or its rootlet. As the limestone contains Cyprides, with the scales and coprolites of fishes, which could only have been deposited in water apparently of a very moderate depth †, we must admit that the thin layers of coal

* Whilst examining the cliffs about three years ago near the entrance of the Brasd'or lake, accompanied by Prof. Johnson of Philadelphia, we found a piece of Stigmaria 6 inches long and 3 inches in diameter, with rootlets attached, in the middle of an upright fossil tree. This could only have been drifted: probably those found in the shales numbered 81, 238, &c. were drifted in the same way.

† The depth of the water could not have exceeded 3 feet, because at that height above the coal we find a soil (underclay) containing the roots (Stigmariæ) of trees which once grew on its surface, unless we assume that the strata had been elevated after the deposition of the coal.

constituting this seam were formed from drifted vegetable matter, for we find layers of carbonaceous and argillaceous shale alternating with three layers of coal whose united thickness amounts only to one foot, which is precisely the arrangement likely to obtain from vegetable matter drifted down with mud into an estuary. If then a seam clearly formed from drifted materials assume this arrangement, it is evident that thick beds of pure coal perfectly free from clay, or mud mixed with vegetable matter, could never have been accumulated in the same manner.

I have marked all the beds in the section in which plants have been found, but it is very probable that they occur in many other beds and have been overlooked. The shales are the most prolific in plants, especially those which form the roofs of the coal-seams. It is a singular fact, that not even the trace of a fossil plant, nor any organic substance has been found in any of the red shales, although they have been carefully examined for that purpose. Wherever erect trees occur, ferns, Asterophyllites, Sphenophylla, and other delicate leaves, are found in the greatest abundance, from which I infer that they fell from growing trees and shrubs, having been covered up by successive layers of fine mud deposited at frequent intervals over a low, marshy district. In these localities single fronds of ferns are sometimes found covering a slab of shale two feet square, as sharp and distinct in their outline as if they had been gathered only yesterday from a recent fern and spread out with the greatest possible care, not a single leaflet being wanting or even doubled up. Some beds also seem to contain one species of plant only, all others being excluded; of this we have a striking example in the argillaceous shale No. 60; in the top of this bed, through a depth of three inches, we find *Asterophyllites foliosa* piled up layer above layer from the base of the cliff to the crop of the bed, a distance of 200 feet, clearly proving that these plants grew on the spot.

Plants are not very common in the sandstones; those numbered 272, 282 and 310 are the only sandstones which contain any considerable quantity: they consist of fragments of Sigillariæ, Lepidodendra, and Calamites confusedly mixed together, and evidently drifted from a distance.

The impressions of Fucoids without any carbonaceous matter are found in several beds, as specified in the section; in every instance they occur on the undersides of hard arenaceous shales or sandstones in contact with soft shales beneath. They appear to have been long tubular stems, from one-tenth of an inch to one inch in diameter, and are accompanied by detached ovate and globular bodies very much like the capsules and vesicles of recent Algæ. Fine ripple-marked sandstones are generally found very near to the Fucoids, and in two instances impressions of rain-drops.

The most interesting fossils in our section are the numerous groups of erect trees situated at so many different levels, which I shall now briefly notice, purposing to send to the Society more detailed descriptions at a future time, having with that view taken an accurate drawing of almost every individual tree.

a. Starting from the base of the section, the first erect tree is met with in the bed of argillaceous shale No. 51, 222 feet above the millstone grit. It is a fluted Sigillaria, 15 inches in diameter and 3 feet high; the base spreads out over the two-inch coal No. 50, but no roots are visible. The interior of the stem is filled with argillaceous shale. See Fig. 5.

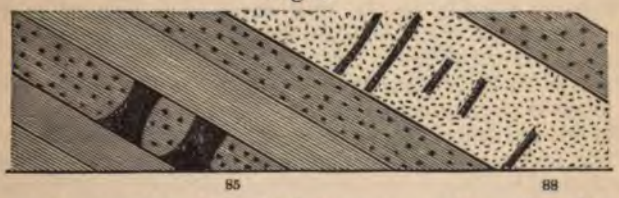
b. In the next superior bed of argillaceous underclay, two upright stems of Sigillariæ occur only 4 feet apart; one is 18 inches and the other 27 inches in diameter at the top, their height being 4 feet. The stems are fluted and covered with a bark of coal three-fourths of an inch thick. They enlarge considerably as they descend, but no roots are visible. We have here conclusive evidence that a slow and gentle subsidence of the coal-measures was in progress during their

Fig. 5.

accumulation; the two-inch coal No. 50, at one period the surface on which the first tree grew, having subsided a depth of eight feet, the shallow water was filled up with mud until it reached the surface, on which the two trees in the underclay No. 52 flourished.

c. At the height of 147 feet above the last trees, and 21 above the Indian Cove Seam, two large stems of fluted Sigillariæ with a coaly bark half an inch thick occur; their length is 5 feet and their dia-

Fig. 6.



meter at the top 24 inches, which increases rapidly as they descend, but no traces of roots can be seen, owing to the soft carbonaceous shale which underlies them having fallen away from beneath.

d. About eight feet higher in the section, several erect Calamites, from 4 to 8 feet in length and 3 to 5 inches in diameter, occur in the micaceous sandstone No. 88. They do not present any traces of roots.

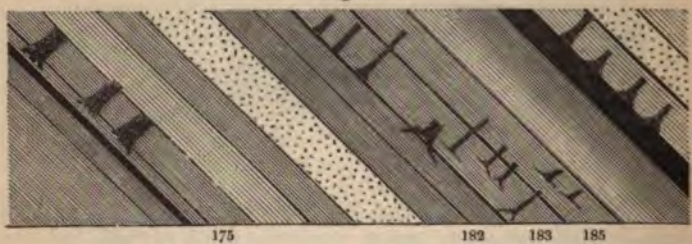
e. Erect Calamites, varying from 3 to 8 feet in height, and about 5 inches in diameter, are also met with in the bed of arenaceous shale No. 119, being 151 feet above the sandstone No. 88, last mentioned. No roots are observable.

f. The next erect trees are found 164 feet higher up, in the sandstone No. 163; here we have two large fluted Sigillariæ, 24 inches in diameter and 5 feet in height, standing only eight feet apart: they enlarge rapidly towards their bases, and were probably rooted on the surface of the three-inch coal No. 161, but being very near the high-water line the surf has washed out the soft, argillaceous shale No. 162 from under the stems, and obliterated all traces of roots.

We now arrive at a group of strata, the lowest only 28 feet above the preceding, exceedingly rich in upright trees, all standing in view together at six distinct levels within a vertical height of 52 feet.

g. The first in the series are three large trunks in the shale No. 175, apparently 30 inches in diameter; they are situated too high up in the cliff to be examined properly; they all bulge out as they descend,

Fig. 7.



and seem to terminate downwards in the argillaceous shale above the coal No. 172.

h. Some of the trees in the beds Nos. 183 and 185 have been already described in the Journal of the Society*; but since that description was written, owing to the constant wasting of the cliffs, several new trees have been exposed, particularly a fine fluted Sigillaria, 18 inches in diameter (seen in fig. 7), with strong roots penetrating downwards at an angle of 45°, and piercing through the three-inch layer of mixed coal and shale No. 182.

i and *k*. In the arenaceous shale No. 183, several small Sigillariæ are found at two distinct levels, some being rooted about the middle of the bed and others near the top. They have Stigmaria roots with rootlets, which, as before mentioned, have already been described in this Journal†.

l. Two small Sigillariæ occur in bed No. 185: Stigmaria roots are seen near them, but not in actual contact.

m. The shale roof No. 189 of the Main Coal has furnished a great number of upright trees with long spreading roots and rootlets, which it is not necessary to enumerate here, three of the most interesting having been described at length in the Journal, viz. a Lepidodendron‡ with Stigmaria-like roots, and two curious specimens of *Sigillaria alternans* §. I may observe that Sigillariæ appear to be the most common, but I have never seen any larger than 14 inches in diameter.

* Vol. ii. p. 393. † *Ibid.* ‡ Vol. iv. p. 46. § Vol. v. p. 354.

n. A long interval now follows without any erect trees, the next in order being Calamites without roots in the sandstone No. 299, which is 735 feet above the Main Coal No. 188.

o. Six feet only above the sandstone last mentioned, a fine erect Sigillaria occurs, based upon the surface of the argillaceous shale No. 302, and extending ten feet upwards into the superincumbent beds. At the height of three feet from the base it is bent over nearly into a horizontal position, the length of the inclined portion

Fig. 8.

being two feet; it then resumes its upright position, which it maintains to the top, terminating under the mixed coal and shale No. 306. The diameter at the top is 15 inches, and at one foot from the base 24 inches. It is furrowed throughout the whole length, but leaf-scars are visible only in the upper portion. Two large roots proceed from the base, but no rootlets or resemblance to Stigmaria can be found.

Prostrate plants and Stigmariæ are found in some of the beds above the shale No. 302, as high up as the top of the sandstone No. 310; but above this sandstone not the trace of a plant of any description can be found until we arrive at the argillaceous shale No. 344, 217 feet above the last upright tree. This shale No. 344 is the commencement of a series of beds exceedingly rich in both prostrate plants and erect trees, which terminate only with the highest bed in our section at Cranberry Head. I have endeavoured to show the position of all the upright trees at one view in the annexed sketch (Fig. 9), the lower portion being visible in the south-eastern face of the cliff, and the

Fig. 9.

upper round the angle of the headland, where the coast-line runs nearly in the direction of the strike of the strata: this will explain why the beds dip so rapidly in one part, and appear nearly horizontal in the other part of the sketch.

p. Four feet and a half below the surface of the shale No. 344, there are a large Lepidodendron and several Calamites. The Lepidodendron, which is the highest tree in the cliff, as shown in the sketch, is 9 feet in height, its diameter at the top being 24, and at the base 36 inches. It is covered with a rough scaly bark of coal 1 inch thick. The trunk is filled up with alternating beds of shale and sandstone with several thin layers of ironstone. I could only trace one piece of root 2 feet in length, which externally was marked in the same scaly manner as the stem, being filled up with soft shale containing small egg-shaped nodules of ironstone. The Calamites, which do not exceed 2 inches in diameter, have long fibrous roots running nearly perpendicularly downwards.

q. I counted ten small upright Calamites and Sigillariæ in the next superior bed No. 345, based upon the surface of the shale No. 344, into which their long fibrous roots penetrated from two to three feet downwards. Two of these Sigillariæ? are about 8 inches in diameter; they are filled with soft friable shale, and have central columns or piths $1\frac{1}{2}$ inch in diameter, composed of pure bright coal arranged in thin horizontal laminæ. There is also the stem of a fluted Sigillaria in the same bed of larger size near high-water mark, but only a small portion can yet be seen.

r. Twenty-three feet higher up, in the arenaceous shale No. 355, there are three large erect trees whose long Stigmaria roots spread over the flat surface of the Cranberry Head bottom seam. One is a Lepidodendron, the two others are Sigillariæ. They are all about 27 inches in diameter, but of different lengths.

s. In the same arenaceous shale No. 355, but four feet above the coal, there are two more trees of about the same size as the last, which are apparently Lepidodendra. Long rootlets run in every direction from their Stigmaria-like roots. These are the last upright trees in our section, making in all eighteen forests, each on a distinct level and consequently of different ages, within a vertical range of 1600 feet, the first being 220 feet above the millstone grit, and the last 40 feet below the highest bed at Cranberry Head.

The animal remains, as will be observed by reference to the section, are chiefly found in the bituminous shales and limestones: in these beds they are very plentiful, but apparently limited to few genera and species. I have only been able to recognize the following*:—*Modiola* (2 sp.), *Spirorbis*, *Unio*, *Microconchus carbonarius*, *Cypris* (2 sp.), and the scales, teeth, &c. of *Holoptychius*, *Megalichthys*, *Palæoniscus*, *Amblypterus* and *Gyrolepis*, which are very abundant, together with vast numbers of coprolites. The *Unio* and *Microconchus* are found alone; the first in the slaty sandstone No. 196, and the latter in the thin limestone No. 92. The *Modiolæ* and

* I made up separate parcels of the shells and ichthyolites, intending to send one to Mr. Conrad of Philadelphia, and the other to Prof. Agassiz of Cambridge, U.S., but by mistake the shells were sent to Prof. Agassiz and the ichthyolites to Mr. Conrad. This has since been remedied, and I hope soon to be favoured with the remarks of those eminent palæontologists on the Sydney fossils.

Cyprides are found with the remains of *Holoptychius* and *Palæoniscus* in the bituminous shales.

On comparing our section with that of the Bay of Fundy coal-measures, although the analogy is in many respects very striking, there is this remarkable difference, that, whilst we have the remains of some decidedly salt-water fish and fucoids at various levels in a section embracing a depth of 1860 feet only, "not a trace of any substance of a marine character" * has been found in the Bay of Fundy section, through a vertical range of 14,570 feet.

Although the great mass of evidence afforded by this section is on the side of those geologists who contend that coal beds were formed from trees or plants which grew upon the spot where the coal now exists, yet we certainly have one distinct example of a thin seam (No. 27) formed from drifted materials deposited in very shallow water.

In conclusion, I may remark, that many interesting phænomena have necessarily been unnoticed in this brief sketch of the lower portion of the productive coal-measures of Sydney, which I shall endeavour to describe in a future communication.

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3. *On the Occurrence of Productive Iron Ore in the Eocene Formations of* HAMPSHIRE. By ALFRED TYLOR, Esq., F.G.S.

THE presence of large ferruginous Septaria, containing carbonized wood, principally in small fragments, was noticed in the lower part of the Barton clays, between Barton Cliff and Muddiford, by Mr. Prestwich and myself about two years ago. At that time we did not proceed west of Christchurch; and I was unable to accompany Mr. Prestwich in his more recent visit to the cliffs between Christchurch and Poole, when Mr. Prestwich also noticed the very ferruginous condition of these large tabular Septaria†.

Having lately had an opportunity of paying a visit to Hengistbury Head, I was much interested in finding that these blocks have been found to contain so large a per-centage of iron as to be available for economic purposes. As productive iron ores have not previously been known to occur in the English tertiaries, I have thought the fact of sufficient interest to be laid before the Geological Society.

Mr. Holloway, of Christchurch, who has undertaken these works, informs me that the occurrence of large masses containing iron in these cliffs appears to have been discovered in the reign of Charles II., during a survey of the adjoining harbour of Christchurch. The king was recommended to establish iron-works here for the purpose of founding cannon; the ore was to be obtained from the shore, and the charcoal from the neighbouring New Forest; this scheme, however, was not carried out. Within the last three years Mr. Holloway sent specimens to South Wales for examination. The first impression of the ironmasters was unfavourable; for although, from the

* President's Address, Quart. Journ. Geol. Soc. vol. ii. p. 179.

† Quarterly Journal of the Geological Society, vol. v. p. 45.

oxidation of the iron, the Septaria presented externally a highly ferruginous crust, yet, when the mass was broken, the grey and earthy fracture more resembled an ordinary compact limestone; and further, the constant occurrence of fragments of carbonized wood presented an appearance to which they were not accustomed. Mr. Holloway, however, informed me that these blocks were found to contain about thirty per cent. of iron, and that, moreover, vegetable matter was present in sufficient quantity to facilitate the reduction of the ore. Many hundred tons of Septaria have been shipped to the iron-works in South Wales; and the works have already attained sufficient importance to induce the proprietor to lay down more than a mile of tram-way, leading along the base of the cliffs to the ancient, but almost deserted, haven of Christchurch.

The headland of Hengistbury projects immediately west of the Downs bordering the haven, and rises to the height of from forty to fifty feet. From this point the cliffs trend in a north-westerly direction for a mile, gradually decreasing in height. As shown by Mr. Prestwich, these cliffs consist of the Barton fossiliferous clays, reposing upon a few feet of fine light-coloured sands. The Septaria occur in three or four bands of such magnitude and regularity that they assume at a short distance the appearance of connected strata.

The encroachment of the sea on this coast has gradually undermined the cliffs, removing the clays and sands, and leaving the shore almost entirely covered with weathered masses of the Septaria. From their size and hardness they have resisted the transporting power of the waves, and extend a considerable distance into the sea, forming the dangerous reef known as Christchurch-ledge. The quantity of such blocks of ore distributed over the beach has been calculated to amount to many thousand tons. This forms the only available source of the material, for although the clays containing these bands of ironstone stretch some distance inland, yet they could not be profitably worked.

The works are of too recent an origin to determine exactly the value of this discovery; but the circumstance of the ironmasters of South Wales continuing, after the experience of last season, to import this ore, proves that it really possesses considerable commercial value.

November 21, 1849.

Charles Myer, Esq., was elected a Fellow of the Society.

The following communications were read:—

1. *On a Cutting in the Railway near* Buckingham.

By William Stowe, Esq.

[Communicated in a letter to the Very Reverend the Dean of Westminster.]

I have great pleasure in sending you some particulars relative to the boulders in our railway cutting, to which you directed my attention last autumn. Many of those you saw have been broken up and

transported as ballast, but some are lying about, and a few remain *in situ*. I have examined all of them, and find they are composed of that variety of oolite which has been named Buckingham or Forest Marble. Many of them are yellowish externally and bluish within, owing probably to a difference in the degree of the oxidation of the iron which has coloured them. The largest I have measured was about 3 feet by 4, very angular, being but little rounded; while the smaller ones, 30 inches by 20, whose corners had been modified and whose sides had been smoothed, were covered with scratches and grooves.

Section of Railway Cutting at Buckingham.

1. Ochreous gravel, with boulders of forest marble, and with Gryphææ, Belemnites, and Ostreæ.
2. Grey gravel.
3. Dark clay, with Belemnites and rolled fragments of chalk.
4. Experimental shaft.
5. Grey sand and gravel.

The cutting (see fig.) is about fifty feet deep, and the boulders are sprinkled among gravel, sand, and clay, about ten or twelve feet below the surface; and are not found lower down among the earlier deposits of smaller pebbles, which must have come *from all quarters*, judging from the variety of rocks they contain. Out of the latter I picked the fragment of fossil bone I sent you a day or two ago—possibly a portion of my old friend the Cetiosaurian, whose tail-bone I sent you some years ago, and which you reported to the Society at the time*.

I found one boulder only with perforations; whether the work of Pholades, or the impression of shells or wood, you will determine from the specimen I send you, taken from one of the largest blocks, and lying nearer the surface than any other.

The country around here is very undulating; scarcely two fields have a similar aspect or inclination, and the hills are capped with gravel, which makes it difficult to trace the stratification. The contortions of the gravel beds are very curious, being in some places almost vertical, and in others twisted like the letter S, according as the bed is cut into obliquely or transversely. The *gravel* has been penetrated to the depth of eighty feet near the pit you saw at Foscot, in search of water, but without success.

Looking at the boulders still *in situ*, I tried to make out from the *scratches* from what direction they had come, but could not satisfy myself on that point.

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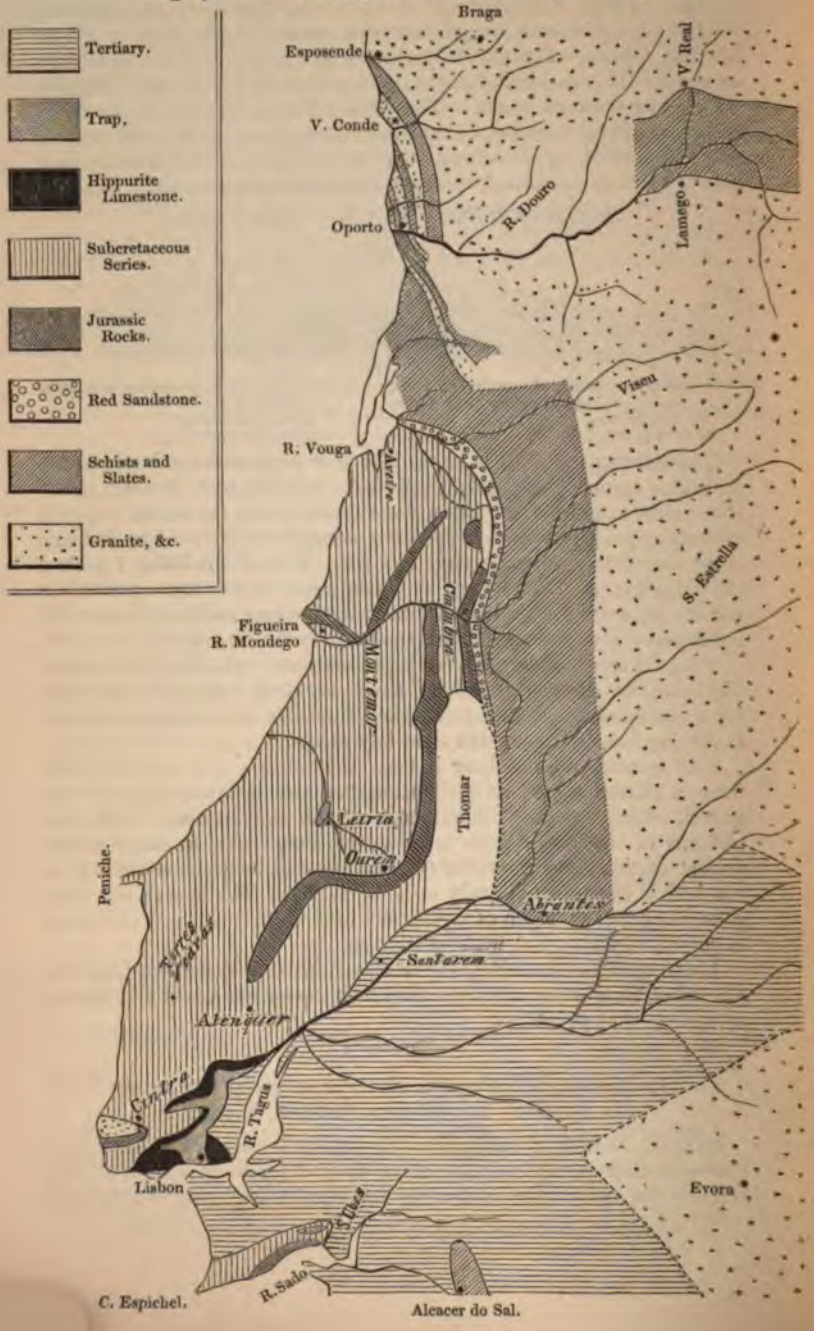
2. *On the Secondary District of* PORTUGAL *which lies on the North of the* TAGUS. By DANIEL SHARPE, Esq., F.G.S.

General Sketch of Portugal.—So little is known of the geology of Portugal that it may be interesting to give a general sketch of that country before proceeding to the details of the district which is to

* Proceedings of the Geological Society, vol. ii. 1833–38, p. 190.

Map of the Secondary District North of the Tagus.



form the subject of the following paper: this has been drawn up from my own observations and from a variety of sources mentioned in their places.

Commencing at the north with the Spanish province of Gallicia, which has been described and roughly mapped by Schulz*, two-thirds of the surface of Gallicia are formed of granite, gneiss, mica-schist, and other crystalline rocks, which cover nearly all the western and middle portions of the province: the eastern side is principally formed of slate, grauwacke, &c., classed by Schulz as *Transition Rocks*, among which we may expect future observers to find the Silurian and Devonian formations. The strike of the slates varies, but its mean appears to be about N.N.W. There are some small patches of secondary red sandstones and marls scattered over the province, of which the age has not been ascertained; here and there a small tertiary deposit occurs; and the bottoms of many of the valleys are filled up with thick deposits of gravel.

Passing southward into Portugal, we find the same formations continued in nearly the same direction: the greater part of the province of Minho and the western side of Traz os Montes consist principally of crystalline rocks; but the rest of Traz os Montes is mostly formed of slates, which are continuous with the same rocks lying on the east of Gallicia.

With occasional interruptions of slates and other rocks, some of which may perhaps be of more modern date, the crystalline rocks are continued towards the S. or S.S.E., in a band forty or fifty miles wide, through the whole extent of Portugal, from the province of Minho to the banks of the Guadiana, including in their range the great mountainous district of the Serra de Estrella: in this course the granites, &c. gradually slope away from the Atlantic and approach the Spanish frontier, while the slates on their eastern flank slope down into Spain. The wild country occupied by the crystalline rocks offers few attractions to travellers, and I can meet with no information about it beyond a few notices in the Appendix to Link's Travels†. The highly cultivated district of the Upper Douro, which supplies all the fine port-wines, has been described by Dr. Rebello de Carvalho‡; it is formed of slate-rocks, supposed by that author to belong to the Silurian system, which strike W.N.W. and are nearly surrounded by granitic mountains.

On the western side of Spanish Estremadura we find the continuation of the crystalline and slaty rocks, which strike about N.W. and are partially concealed by the tertiary deposits of the basin of the Upper Guadiana§.

The great granitic band above-mentioned is flanked on its western

* Descripcion Geognostica del Reino de Galicia por Don Guilhermo Schulz. Madrid 1835.

† Geologische und mineralogische Bemerkungen auf einer Reise durch das südwestliche Europa, besonders Portugal, von F. Link, 1801.

‡ Consideraçoes Geraes sobre a Constituiçao Geologica do Alto Douro, por Jozé Pinto Rebello de Carvalho. Porto, 1848.

§ An excellent account and map of this district have been published by Le Play, Annales des Mines, 3rd series, vol. vi. 1834.

side by various slaty and schistose rocks. I have already described to this Society a portion of these*, which beginning on the north at Esposende, line the coast as far as the Vouga, with the exception of a range of crystalline rocks, of which the granite of Oporto is the central axis. Near Vallongo a bed of anthracite coal underlies Lower Silurian slates, which form part of this series. From the mouth of the Vouga the schists run S.E., keeping on the north side of that river: they then turn southward, and after running along the Serra de Busaco, pass about four miles to the east of Coimbra, and continue along the little river Deuça, and then down the lower part of the Zezere to the Tagus near Abrantes. The district which lies between the schists just mentioned and the Atlantic, bounded on the south by the Tagus, and covered for the most part with secondary deposits, forms the subject of this memoir; but before entering on its description, I will carry this short summary through the South of Portugal.

Proceeding southward from Abrantes, we descend into the great tertiary basin, through which the Tagus and the Sado reach the sea; this tertiary area covers between 2000 and 3000 square miles, and is only interrupted by the ridge of secondary rocks extending from St. Ubes to Cape Espichel. Near the sea the tertiary deposits are all of marine origin, and the most important part of the series, called in my former paper† the *Almada beds*, has been shown by Mr. James Smith‡ to be of the miocene period. The Almada beds extend up the Tagus to Verdelha; about fifteen miles higher up the river, the hills on the north bank of the Tagus, rising to a height of perhaps 200 feet, consist of brown marl overlaid by soft rubbly limestone, containing *Lymnæa longiscata*, Sow., a shell common to the fresh-water beds of the eocene and miocene periods. I traced these beds of lacustrine limestone from Cartaxo by Santarem towards Golegão: they are not found near the mouth of the Tagus, and are perhaps the lacustrine equivalents of the marine Almada beds.

A little above Villa Franca I met with a bed of marl about fifty feet above the present level of the Tagus, containing the common *Lutraria compressa*, and in the marshy flat near Villa Nova da Rainha the same shell and a small variety of *Cardium edule*, both of which now live in abundance in the estuary of the Tagus near Lisbon; so that it is evident that this part of the country has been upheaved at least fifty feet within a comparatively recent period. The upper part of the tertiary basin forms a great marshy district, which will probably prove to consist of lacustrine or fluviatile deposits of very modern date.

On the north side of Lisbon a great area is covered with basalt, which separates the secondary from the tertiary formations. The

* Quarterly Journal of the Geological Society, vol. v. p. 142.

† On the Geology of the Neighbourhood of Lisbon. Trans. of Geol. Soc. 2nd series, vol. vi. p 107.

‡ On the Age of the Tertiary Beds of the Tagus. Quart. Journ. Geol. Soc. vol. iii. p. 410.

line of demarcation between these two great systems is as strongly marked in Portugal as it is in our own country.

On the south of the tertiary basin, the centre of the province of Alemtejo is covered by secondary beds, probably older than those to be described on the north of the Tagus, but the true age of which has not yet been determined: these are bounded on the south by the lofty chain of hills, called the Serra de Monchique and Serra de Caldeirão, which separate Alemtejo from Algarve, and which consist of schists and slates, with the exception of granite at the Cabeça de Monchique. Dr. Welwitsch has informed me that schists also occur along the coast of Alemtejo from Cape Serdão to Sines, and that the Cape of Sines is formed of syenite.

On the south of the chain of Monchique and Caldeirão lies the little kingdom of Algarve, which has been carefully surveyed by M. Bonnet, from whom we may hope to receive a geological description of it; that gentleman told me that a band of secondary rocks lies on the south flank of the schistose chain, which is again overlaid along the south coast by tertiary deposits. Considerable outbursts of trap near Cape St. Vincent are mentioned by Link.

Thus it appears that there are two districts of secondary and tertiary rocks in Portugal; the southern of which consists of the narrow strip of Algarve; the other commencing on the north side of the Algarve mountains extends up to the Vouga, forming a narrow triangle of which the base at the south is about forty miles long, and the height from north to south is about 200 miles: the secondary rocks of this latter area are divided into two parts by the tertiary basin of the Tagus and Sado. It is the northern division of this secondary district, viz. that which lies to the north of the Tagus (see fig. 1), which I now propose to describe.

Throughout this paper I shall commence with the upper formations, and describe them in descending order under the following heads:—

Hippurite limestone, equivalent to our chalk.

Subcretaceous series.

Jurassic series.

Sandstones of undetermined age.

With the exception of certain deposits of sandstone last mentioned, no secondary rocks older than the lias have been seen in Portugal north of the Tagus; nor have any traces of the carboniferous series been met with in any part of Portugal.

Hippurite Limestone; equivalent to the Chalk of the North of Europe.

The description of this formation will be found in my paper on the 'Geology of the Neighbourhood of Lisbon,' p. 115; and as this rock does not occur to the north of the district described in that memoir, I have little to add to the account there given of it.

The hippurite limestone is the uppermost of the secondary deposits, and near Lisbon is usually overlaid by basalt, which bursts out in great quantities in that neighbourhood in the interval between

the deposition of the secondary and tertiary formations, and which covers a large tract round Lisbon.

There are three separate patches of the hippurite limestone; one of these is on the west side of Lisbon and extends a few miles down the river to Belem; this mass of limestone has been thrown into a saddle, of which the axis runs down the valley of Alcantara, just outside the city, with a direction of about N. 30° W., on each side of which the beds dip away from the axis at angles of 5° to 10°; the limestone of many of the beds is shattered to a remarkable degree, and intersected by fissures which run in a direction parallel in the main to the line of the valley, but are waved and irregular. Several of these are sometimes seen in the thickness of a foot, while others are two or three feet apart. There are also three lines on which the beds have been unconformably deposited upon those below, and the fissures just mentioned commence above the lowest of these and end at the upper one; yet notwithstanding their unconformable deposition, the same species of shells are found through all the beds. Therefore the disturbing forces must have acted during the deposition of the formation.

The quarries on both sides of this valley furnish an inexhaustible supply of organic remains.

Another range of hippurite limestone extends from the shore of Cascaes Bay towards the north-east nearly to Loures, and also spreads out along the coast eastward beyond Passo d'Arcos: many of the hills of limestone are covered with detached masses of basalt, which is itself frequently capped by tertiary beds: and between Oeiras and Fort St. Julian the limestone is directly covered by a large patch of the Almada tertiary limestone full of its usual fossils.

The remaining line of hippurite limestone reaches from Montelavar and Pero Pinheiro to the hills immediately south of Bucellas, in which a good section is exposed in the ravine leading from Tojal towards Bucellas. At Pero Pinheiro the limestone has been largely quarried and organic remains are plentiful. To the south-west of this place a little correction is required in my map published in our 'Transactions,' vol. vi. pl. 14: the limestone instead of stopping at the farm of Quinta Granzea should be continued in a thin zone round the southern edge of the basalt, till it meets the sandstone on the north of Algeirão.

The hippurite limestone is laid down in the map just referred to between Villa Franca and Trancozo, and again as extending from Villa Franca to the north-west beyond Alenquer: this is an error in each case, into which I was led by the great resemblance in the mineral character of these limestones to that of the hippurite limestone, not having then collected many organic remains: subsequent examination has shown that the limestones in question belong to the lower part of the subcretaceous series, under which head they will be described in due course.

It appears therefore that the hippurite limestone is not to be seen to the north of Bucellas; nor have I seen it *in situ* anywhere beyond the neighbourhood of Lisbon; but it is probable that it occurs near

Seville, as the church of the Hospital de Sangre in that city is built of a rose-coloured marble closely resembling that of Pero Pinheiro, and full of the same species of *Caprinula* and *Sphærulites* as are found in the hippurite limestone near Lisbon.

I have only to add a list of the organic remains found in this formation, by which it will be seen that all the species known elsewhere belong to the chalk or greensand. Coupling with this the fact that the hippurite limestone is the uppermost bed of the secondary series in Portugal, we cannot hesitate to class it as the equivalent of the chalk of northern Europe.

It is remarkable that fifty-five per cent. of the species found in this formation are new, only forty-five per cent. being known to the north of the Pyrenees. It is also worthy of notice that no cephalopods nor brachiopods have been found in the hippurite limestone. I shall return to this subject before concluding. From the close proximity to Lisbon of the quarries in the valley of Alcantara, I had far more opportunities of collecting fossils from this than from any of the lower formations: the following table is therefore more nearly complete than any of the succeeding lists.

Organic Remains of the Hippurite Limestone near Lisbon.

Astræa? (one species).
Echinus Olisiponensis, n. s.
Brissus scutiger, n. s.
Arca Moutoniana, *D'Orb.*
—— Olisiponensis, n. s.
—— Passyana, *D'Orb.*
Avicula Olisiponensis, n. s.
Caprinula brevis, n. s.
—— Boissyi, *D'Orb.*
—— d'Orbignii, n. s.
—— Doublieri, *D'Orb. sp.*
Cardium corrugatum, n. s.
—— Olisiponense, n. s.
Cyprina cordata, n. s.
—— globosa, n. s.
Diceras Favri, n. s.
Exogyra Olisiponensis, n. s.
Exogyra plicata, *Lam.*
Isocardia cretacea?, *Goldf.*
Ostræa globosa, *Sow.*
Pecten inconstans, n. s.
—— striatocostatus, *Goldf.*
Perna? fragilis, n. s.
Pholadomya Ligeriensis, *D'Orb.*
Nerinæa Eschwegii, n. s.
—— nobilis, *Goldf.*
—— Olisiponensis, n. s.
Tylostoma globosum, n. s.
—— ovatum, n. s.
Sphærulites angeiodes, *Lam.*
—— cylindracea, *Des Moulins.*
—— Ponsiana, *D'Archiac.*
—— Sauvagesii, *D'Orb.*
—— ventricosa, *Lam.*

Lowest beds of the formation at Papel on the road from Lisbon to Cintra.

Anomia convexa, *Sow.*
Arca Moutoniana, *D'Orb.*
Artemis elegantula, n. s.

Lowest beds of the formation near Bucellas.

Cardium corrugatum, n. s.

Subcretaceous series, including the Red Sandstone Formation and the Espichel Limestone of my paper of 1839.

The hippuritē limestone rests, with a deceptive appearance of conformity, upon ferruginous sands belonging to different portions of a very extensive series of beds, which are here considered together,

since it has not been found practicable to subdivide them into separate formations, notwithstanding their great thickness and complexity. The series consist of various alternations of sands or sandstones with limestone, and appears to represent, on a far larger scale of development, the beds which in England lie between the chalk and the oolites.

Reaching from the Bay of Cascaes to the mouth of the Vouga, these subcretaceous rocks line the coast of Portugal for about 150 miles, except at the sea-board extremity of the Cintra Hills and the point of Cape Mondego. The breadth of country covered by them varies from twenty to forty miles. Throughout this district the continuity of the subcretaceous beds is occasionally interrupted; being broken through by the granite of Cintra and beds raised up in contact with that rock, by several great chains of limestone belonging to the oolitic series, upon which the subcretaceous beds rest unconformably, and by several local outbursts of trap. Nevertheless the subcretaceous rocks probably cover more than nine-tenths of the secondary district on the north of the Tagus.

The difficulty of subdividing this great series arises from the close resemblance of the different beds of limestone, and from the faint traces of bedding in the loose, incoherent, ferruginous sands. Where there are no beds of limestone, whole districts consist of great masses of sand and gravel, in which it is difficult to find the direction of the dip or to trace any clear order of superposition; the whole almost resembling a mass of diluvial gravel. Organic remains are very rare in the sandstones, but they are abundant in most of the beds of limestone belonging to this series, and they offer differences by means of which we obtain some idea of the relative ages of the beds seen in distant parts of the district: but it will require a farther examination of the country before all the difficulties connected with this formation can be solved.

The beds of limestone are most prevalent between fifteen and forty miles north and west of Lisbon, and become more and more rare as we proceed northward; this may be partly due to differences in the age of the beds, but is probably also owing to irregularity in the deposition of the limestones, which seem to be local deposits intercalated in a great arenaceous formation; as the Kentish-rag limestone, in England, is a most variable and uncertain companion to sandstones of about the same age as those under consideration.

In travelling southward from the north of Portugal, the subcretaceous beds are first seen two or three miles to the south of the Vouga: their northern boundary runs from N.W. to S.E., nearly parallel to the course of that river: they consist of coarse incoherent sandstones and sands with little trace of bedding, and closely resemble the superficial gravel with which that part of the country is covered. The low plains round Aveiro are so completely covered with gravel that the northern edge of the sands is concealed near that city, but at Serdão they are seen dipping S.E. 5°, and resting unconformably on an older formation of red sandstone that dips at the line of junction S. 30°, and which is described in the sequel.

Some insignificant and nearly horizontal beds of limestone are seen interstratified with the sands near Mamarosa, about three leagues from Aveiro on the road to Coimbra; in these were found

Pecten quinquecostatus, *Sow.*
Exogyra conica, *Sow.*
Diadema Lusitanicum, n. s.

The first two, being common in the north of Europe in the upper greensand, show us that the limestones of Mamarosa belong to the uppermost part of the subcretaceous series. Below the limestones there is a repetition of coarse ferruginous sands and incoherent sandstones, all of which might be easily confounded with the modern gravel but for the guide afforded by the fossiliferous beds of limestone.

The position of the beds along this part of the country will be seen in section No. 1 (fig. 2), drawn from Aveiro to Coimbra.

At Vendas Novas, four leagues N.W. of Coimbra on the Aveiro road, and also at Mealhada, three leagues north of Coimbra on the Oporto road, beds of a grey argillaceous limestone, nearly horizontal, are seen below the sands of the subcretaceous series; these limestones contain fossils of the age of the lias which will be enumerated in their place; the limestones are of no great breadth, and on passing them we find again the same slightly ferruginous sands, occasionally containing some insignificant beds of limestone, which continue to the village of Sarjento-mór, about six miles north of Coimbra, where several thin beds of limestone, very full of shells, crop out with a slight dip N.W., resting on a loose sandstone.

The species found at this spot are the following:—

Exogyra conica, *Sow.*
Pecten æquicostatus, *Lam.*
Plicatula pectenoides, *Sow.*
Natica bulimoides, *Leymerie sp.*
Nerinæa cylindrica, *Voltz.*
Nerinæa Conimbrica, n. s.
Tylostoma ovatum, n. s.
—— globosum, n. s.
—— punctatum, n. s.

The first four species in this list are well-known shells of the greensand, and the first-named two species of *Tylostoma* are common in all the upper portions of the subcretaceous beds of Portugal, and are also found in the hippurite limestone at Lisbon; so that we may safely refer this limestone to the upper portion of the subcretaceous series, notwithstanding the presence of the *Nerinæa cylindrica*, which in Germany is found in the Kimmeridge clay.

This bed of limestone continues towards the S.W., and was seen again in that direction at San Fagundo, where I collected

Tylostoma ovatum, n. s.,
—— globosum, n. s.,
Tylostoma Torrubiæ, n. s.;

from thence it is probably continued southward to Condeixa, which stands on a horizontal bed of similar limestone, containing

Tylostoma ovatum, n. s.,
Tylostoma Torrubiæ, n. s.;

at both these two places the shells of the genus *Tylostoma* are excessively abundant.

Both at Condeixa and Sarjento-mór the bed of limestone just men-

Fig. 2.—*Section No.* 1. *From Aveiro to Coimbra.* (35 miles.)

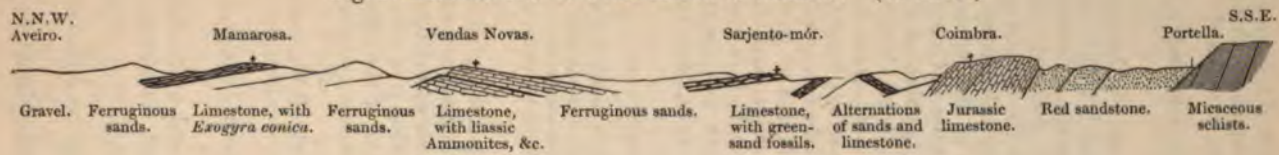


Fig. 3.—*Section No.* 2. *From the Ponte de Mayorca to Coimbra.* (20 miles.)

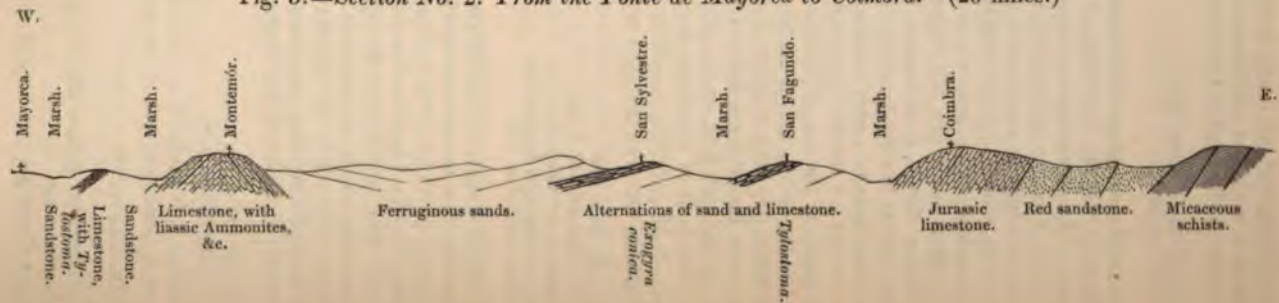


Fig. 4.—*Section No. 3. From Leiria to Thomar.* (30 miles.)

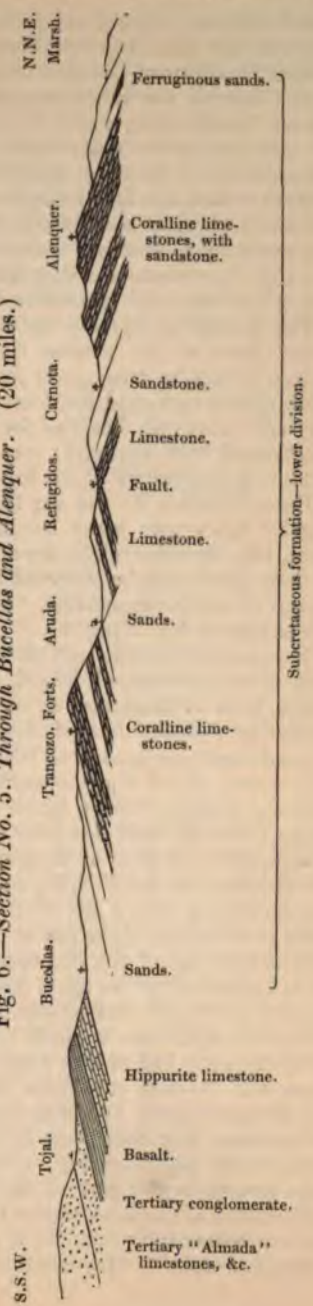


Fig. 6.—*Section No. 5. Through Bucellas and Alenquer.* (20 miles.)

tioned rests on red marl and ferruginous sands, also belonging apparently to the subcretaceous series, and resting unconformably on the jurassic limestone of Coimbra described farther on.

At Condeixa the subcretaceous beds are overlaid by an extensive deposit of travertine, which is spread out in irregular patches over the low country for many miles round that town; in many places the travertine is twenty or thirty feet thick; it consists of a variable mixture of sand and lime brought down by the streams of water which traverse the beds of sandstone and limestone of the neighbouring hills and break out in powerful springs at their base, the sand being rolled down by the streams and then united by a compact cement of lime which had been held in solution in the water.

The travertine appears to have been forming from a remote period down to the present time; in the neighbourhood of the springs it may be seen newly formed and quite soft; below this it forms a solid rock, and the lower and older beds are so hard that they are extensively quarried for millstones, which have a great reputation all over Portugal: some of the lower beds contain many stems and impressions of the leaves of dicotyledonous plants.

From Coimbra to the sea the Mondego runs through a broad marshy valley with many lateral branches of considerable extent; these, like the main valley, are on the line of great faults: hence the sections which may be observed in the hills enclosing the river have a want of regular connection. I followed the north bank along the line of section No. 2 (fig. 3).

The jurassic limestone of Coimbra is overlaid unconformably, as has been already mentioned, by red sands and marls with some subordinate beds of limestone, in one of which at San Fagundo three species of *Tylostoma* are abundant; this is covered to the westward by sands and loose sandstone, containing occasional beds of limestone, with a very slight dip westward: the only shell observed in these beds was *Exogyra conica*, which is very common in most of the limestones. Similar beds continue to Montemor-velho, where they are interrupted by a ridge of limestone hills running from the bank of the Mondego to the N.N.E., on which the subcretaceous beds rest unconformably with a dip of 3° W. The limestone of Montemor-velho is of the age of the lias or of the lower part of the oolitic series. On the west side of the Montemor ridge is a flat marsh, on a line of fault, beyond which we again come to the subcretaceous sandstones dipping N.W. 30°, and containing a bed of limestone about 100 feet thick with abundance of shells of the genus *Tylostoma*; this is probably the same bed as that seen near Coimbra at Condeixa and San Fagundo. Beyond the Ponte de Mayorca, which crosses a broad marsh following the line of an important fault, lies a thick formation of limestone near the village of Mayorca; this I failed to examine owing to the night coming on, but M. Bonnet, who had resided for some months in this part of the country, informed me that it is the continuation of the limestone of Cape Mondego, which I shall shortly show to belong to the middle of the oolitic period.

The limestone of Mayorca is overlaid by a thick deposit of ferru-

ginous sand and coarse sandstone striking nearly E. and W. which continues to Buarcos: this sandstone is overlaid by a formation of hard whitish argillaceous limestone between 100 and 200 feet thick which dips S.S.W. 15°, and forms the northern bank of the Mondego for about six miles, extending from the fort at the entrance of the river, and passing under the little town of Figueira to the first great bend of the river: during this course, the limestone rises from the water's edge to the top of the hills which bound the river. If continued in the same direction to the eastward, the Figueira limestone would cross the Mondego and extend towards Soure, through a part of the country which I did not examine.

The Figueira limestone is rich in fossils, but it is so hard that they are not easily extracted; the following were found between the town and the fort:—

Exogyra conica, *Sow.*
Gryphæa columba, *Lam.*, very abundant.
Pecten Dutemplei, *D'Orb.*
Turritella Vibrayana, *D'Orb.*
Turbo Mundæ, n. s.
Tylostoma Torrubiæ, n. s.
Nerinæa Mundæ, n. s.
Echinopsis subuculus, n. s.
Cidaris lævisuscula, *Agassiz.*
Toxaster Couloni?, *Agassiz.*
Brissus subdepressus, n. s.
Scalaria, fragments.
Turritella, fragments.

These species indicate that we are still in the upper portion of the subcretaceous series. The most abundant and characteristic shell in this locality is the *Gryphæa columba*, which I have not met with elsewhere in Portugal. In mineral character and in its greater thickness and compactness, the Figueira limestone differs from all the beds of subcretaceous limestone yet described, which, added to some difference in organic remains, makes it probable that it is a different bed.

There is a good descending section along the coast from Figueira to Cape Mondego in the following order:—

Figueira limestone, dip S.S.W. 15°.

Calcareous sandstone, dip S.S.W. 15° (a few feet only).

Soft light brown sandstone, dip for about one mile S.S.W. 15°, then changing gradually to S.S.W. 10°; this sandstone passes into a hard, dark, ferruginous, calcareous conglomerate, and then into a hard red grit, dip S.S.W. 10°, on which stands the village of Buarcos.

West of Buarcos are various red sandstones of softer character, with occasional alternations of red marl, dipping first E.S.E. 15°, and then S.E. 40°; these rest on a series of beds of sandstone alternating with limestone, the organic remains of which belong to the upper part of the oolitic series; below this is the coal series of Cape Mondego resting on limestones indicative of the middle portion of the oolites, which will be described in detail farther on.

There is a gradual passage from the Figueira limestone down to the sandstone of Buarcos; so also there is a passage from the sandstone west of Buarcos down to the base of the jurassic series of Cape Mondego: and if this section alone were considered, it might be thought that we had here a passage from the subcretaceous to the jurassic formation; but this cannot be the case, for as we proceed southward we shall meet with subcretaceous beds of an older date

than those of Figueira and Buarcos, and with jurassic limestones more modern than those of Cape Mondego. We must therefore presume that there is a complete break in the series at the line where the dip changes on the west of Buarcos, although the aspect of the country does not indicate any great change, and the sandstones on the two sides of the line of fault are not of very different character; and that this is a case, of which we shall meet other examples, where the resemblance of sandstones and sands of different ages, but in close contact, makes it difficult to draw the exact line between two formations, the difference of which is sufficiently marked at a moderate distance from the line of junction.

If we review the whole extent of the subcretaceous beds on the north of the Mondego, we see that (except near Figueira) they usually strike from N.N.E. to S.S.W. with a very slight dip to the W.N.W.: guided by this clue and by the light afforded by the organic remains, we may class the beds roughly in the following descending order:—

Sand: in all the N.W. part of the district.
Sand and loose sandstone with alternations of thin beds of limestone, in which the commonest fossil is the *Exogyra conica*.
Sands and sandstone.
Limestone of Sarjento-mór, San Fagundo, Condeixa, and the hill west of Montemór, abounding with various species of *Tylostoma*, &c.
Red sands and red marls, round the Coimbra limestone.

The above form a connected series; below these we must place the following, leaving it doubtful whether there is any gap in this part of the series:—

Limestone of Figueira, with *Gryphæa columba* and numerous other fossils.
Sandstones and grits between Figueira and Buarcos.

These include all the subcretaceous beds seen on the north of the Mondego.

Near Coimbra the various formations cross the Mondego with only a slight derangement of their course; and I have already described the continuation of the subcretaceous beds to Condeixa: to the west of the latter town they are separated from the great western expanse of the formation by a chain of jurassic limestone which reaches continuously for above sixty miles from near the Mondego to Monte Junto, about forty miles north of Lisbon, which will be described in its place. I did not follow the beds to the eastward of this chain below Condeixa, nor did I examine the hills along the south bank of the Mondego.

From the mouth of the Mondego opposite Figueira to Leiria, the road crosses a great extent of ferruginous sands and loose sandstones with very few beds of limestone, the whole covered by a considerable deposit of coarse gravel, which is both coarser and more abundant near the sea and diminishes as we proceed inland. This is a dreary district principally covered by barren heaths or pine woods. The beds are nearly horizontal with occasional changes of dip. This ap-

pears to be a repetition of the country lying to the south-west of Aveiro, and probably belongs like that to the uppermost part of the subcretaceous group. Between Leiria and Redinha, the road from Lisbon to Oporto crosses similar beds of ferruginous sand. Thus we have here lost the fossiliferous limestones seen on the north bank of the Mondego, and seem to begin again at the top of the subcretaceous series.

Leiria stands on a mass of trap which has thrown up and altered the beds in contact with it. On the east side of the town a bed of limestone, dipping E. 45°, rests on the trap.

Eastward of Leiria is a continuation of the ferruginous sands and gravels for about four miles, where they overlie a limestone nearly 100 feet thick, dipping N.W. 5°, and containing *Exogyra plicata*, Lam., *Ostræa*, &c. Eastward of this for several miles the country consists of hills of coarse sand, gravel, and sandstone, with some few beds of limestone. Towards Aldea da Cruz and Ourem the limestones are rather more important, dipping westward 2° or 3°. The old town of Ourem stands on a conical hill of sand and gravel capped by a bed of compact white limestone nearly horizontal, and containing

Exogyra plicata, *Lam.* Cidaris.
Mytilus ornatus, *D'Orb.*

The gravel below the limestone exactly resembles the modern superficial drift which covers the low country near the sea, but fortunately the overlying limestone with its cretaceous fossils preserves us from error on this head, and enables us to estimate the age of other similar gravel beds in the district.

For five or six miles farther east are beds of ferruginous sand, similar to those so often described, containing some insignificant beds of limestone, and dipping W. 3°.

The preceding series rests on the jurassic rocks of the great limestone chain already mentioned, which here dip E.S.E. 10°, consisting of a compact white limestone of great thickness, resting on soft ferruginous sandstones alternating with limestone, which latter beds are but slightly exposed on the western flank of the chain. The section No. 3 (fig. 4) explains the position of the beds along the line just described.

From the mouth of the Mondego to the boundary of the formation beyond Ourem, we appear to have a gradually descending series of beds; but from their very slight inclination they may be of no great total thickness, notwithstanding their covering a considerable extent of country: the whole appear to belong to the upper part of the subcretaceous series. The *Exogyra plicata* here takes the place of the *Exogyra conica*, which is so abundant north of the Mondego: as we proceed southward we lose the latter species, and the *E. plicata* becomes more abundant, and is throughout a large district round Lisbon the most characteristic shell of the cretaceous and upper half of the subcretaceous series.

To the south of Leiria the principal rock is still a coarse ferruginous sand, but the alternations of limestone are more frequent; all the beds are much disturbed, and there are frequent changes of dip,

caused apparently by the eruption of igneous rocks to which the trap of Leiria belongs: one mile south of the town are some beds of grey argillaceous limestone, dipping E.S.E. 30°; a little farther south the road crosses several beds of limestone alternating with sandstone, dip S.S.E. 45°. Some of the limestones are full of a small oyster, others are almost entirely composed of the shells of *Perna rugosa*, Goldfuss, a shell found in Germany among the oolites: perhaps a jurassic bed of limestone is here thrown up to the surface, among the sandstones of the subcretaceous series. Near Batalha we escape from the disturbing influence of the trap, and the beds resume their more usual dip of N.N.W. 10°; among some other small shells, I found between Leiria and Batalha *Corbula carinata*?, D'Orbigny, a greensand species. Some considerable beds of limestone pass through Aljubarota, running S.S.W. with a dip varying between S.W. 10° and N.E. 5°: they contain

Perna lanceolata, *Geinitz*.	Trigonia, a fragment.
Lithodomus prælongus?, *D'Orb*.	Corals, various.

Below this to the eastward are the usual sands, with a thick bed of limestone near Candieiros, containing

Terebratula Moutoniana, *D'Orb*.

These fossils show that the beds all belong to the subcretaceous series*.

From Carvalhos near Batalha to the southern extremity of Monte Junto, the subcretaceous beds rest unconformably and at a low angle on the base of the high ridge of hills of jurassic limestone already alluded to, in which the beds, dipping to the east or west in different parts of their courses, are frequently highly inclined and much disturbed.

The country between the jurassic limestone beds just mentioned and the sea consists for the most part of sand and sandstone, and for many miles round Caldas da Rainha there is scarcely a trace of limestone: the sand beds in that neighbourhood probably belong to the upper part of the series, which is everywhere principally composed of ferruginous sands†.

The subcretaceous beds continue to cover the country to the southward, but I am not able to give a connected account of them in that direction, and must pass on to the country covered by them to the north-west of Lisbon and north of Cintra.

The uppermost beds of the subcretaceous series near Lisbon are the ferruginous sands which come out from below the hippurite limestone along a line reaching from the coast of the Bay of Cascaes nearly to Loures, usually with a considerable dip to the S.W.; these

* Some additional specimens since received make it probable that the limestones of Leiria and Aljubarota belong to the lowest part of the subcretaceous series, and may be identical with the limestones seen between Sobral and Torres Vedras and at Alenquer.

† A bed of asphalte has been found in this part of the series to the west of Alcabaça, but I can give no details respecting it, as I did not visit the spot.

contain some beds of red and variegated marls, and the thin bed of lignite mentioned in my former paper (p. 119). Below these we find a great thickness of limestones, alternating first with sandstone and lower down with shale, very rich in fossils; these beds encircle the Cintra hills, near which they are thrown up to a high angle: details of their position will be found in the sections pl. 15 of the sixth volume of our 'Transactions.' The lower part of this series was separated in my former paper under the name of the "*Espichel Limestone*," but a farther examination of the country and a careful scrutiny of large collections of fossils from both parts of the series have convinced me that the whole belong to one formation, and that the separation of the *Espichel Limestone* must be given up.

I have also to correct an error in mapping the district on the north side of the Cintra hills (vol. vi. pl. 14 and 15, sections 2 and 5), where the San Pedro limestone and slate-clay are marked as if continued round the north side of the chain. These two formations are well exposed on the east side of the Cintra hills, but they stop a little to the north of the village of San Pedro, and from Cintra to the coast the subcretaceous limestones rest immediately on the granite. The limestones in contact with the granite are all altered into white semicrystalline marble, and this uniformity of their mineral character led me to refer them all to one formation at a time when I had not studied their different organic remains.

The cliffs north of Cape Rock afford excellent opportunities for examining the beds of the calcareous division of the formation and for collecting their fossils in great abundance. The lowest beds which abut against the granite are nearly perpendicular, the limestones are much altered in character, and the shells contained in them are too much flattened to be identified; among these a gigantic *Arca* is the most abundant. The next beds are seen at the Praia de Adrarga, those a little higher in the series at the Praia de Maçams and Praia de Lagoa, at all of which localities organic remains are very abundant: the following lists contain those which I collected. With the single exception of *Nerinæa cylindrica*, all the previously known species found in these localities belong either to the chalk or the greensand, and many of them are also found in the hippurite limestone close to Lisbon; therefore these calcareous beds clearly belong to the subcretaceous series, of which they form the middle portion. The *Nerinæa cylindrica* is found in Germany among the oolites, but it was seen again near Coimbra in the upper beds of the subcretaceous series.

Organic remains found in the cliffs at the Praia de Maçams, north of the Cintra hills.

Diadema rude, n. s.
Nerinæa Titan, n. s.
—— Olisiponensis, n. s.
Turritella Cintrana, n. s.
—— Renauxiana, *D'Orb.*
Anomia convexa, *Sow.*
—— lævigata, *Sow.*
Artemis inelegans, n. s.
Diceras Favri, n. s.
Exogyra plicata, *Lam.*
Ostræa prælonga, n. s.
Pecten quinquecostatus, *Sow.*
Sphærulites Marticensis?, *D'Orb.* sp.
—— undetermined.

At the Praia de Lagoa, near the preceding.

Natica prælonga, *Deshayes.* Pholadomya Royana?, *D'Orb.*

At the Praia de Adrarga, north of the Cintra hills.

Nerinæa Archimedis, *D'Orb.*
—— cylindrica, *Voltz.*
Pyramidella sagittata, n. s.
Ostræa colubrina, *Lam.*
Pecten striato-costatus, *Goldf.*
Trigonia caudata, *Agassiz.* (*T. scabra*, Morris's Catalogue.)

At Fontanellas, north of Cintra.

Cardium corrugatum, n. s.

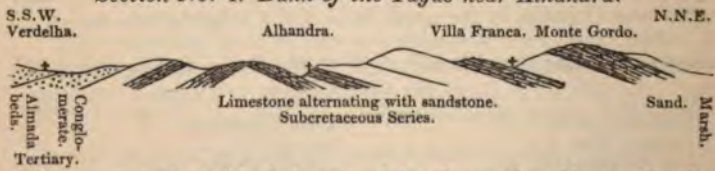
Both at the Praia de Adrarga and the Praia de Maçams the limestones have been disturbed by various eruptions of trap, which appear to have burst out during the formation of the subcretaceous beds, with some of which they are very irregularly interstratified, while others are displaced by them: in connection with the trap is a mass of argillaceous breccia, evidently of igneous origin and of considerable thickness, which interrupts the series of stratified deposits. These trappean beds are continued in a band round the Cintra hills, but they do not belong to one formation, as described in my former paper (Trans. vol. vi. p. 122), but pass through the different rocks which encircle the granite.

The beds of the calcareous middle division of the subcretaceous series cover the country north of Cintra for many miles, extending beyond Mafra and Ericeira, and resting upon ferruginous sands, which on the Caldas road are met with before reaching Torres Vedras.

The lowest part of the subcretaceous series is largely developed in the district which lies to the north-east of Lisbon, bounded by the Tagus from near Verdelha to Villa Franca. The great elevatory movement which has thrown up the jurassic rocks of Monte Junto was continued with less intensity to the southward as far as Alhandra, raising up all the lower beds of the subcretaceous series into an anticlinal of which the axis meets the Tagus at that place. This is seen in section No. 4 (fig. 5), which shows the position of the beds along the bank of the Tagus from Verdelha to Villa Franca.

Fig. 5.

Section No. 4. Bank of the Tagus near Alhandra.



The same series of beds is crossed by the section No. 5 (fig. 6), drawn nearly parallel to the last from Bucellas to Alenquer along a line of traverse which I examined in some detail.

From Bucellas to Refugidos, a distance of about seven and a half

miles, the beds are crossed in a descending order: their dip is generally to the S.W. at angles rarely exceeding 10°, but there are also some minor disturbances which spread them over a greater breadth of country than they would otherwise cover: the axis of elevation passes near Refugidos, beyond which spot the section re-crosses the same beds with a contrary dip in an ascending order. The following is the series seen in the first half of the section.

Between Tojal and Bucellas the ferruginous sands and sandstones of the subcretaceous series are seen overlaid by the hippurite limestone which there dips S.S.W. 15°: near Bucellas these sands dip S.W. 10°, and contain some unimportant beds of limestone: they closely resemble the upper division of the subcretaceous sands seen on the west of Lisbon, and appear to lie conformably under the hippurite limestone; yet it is probable that this is deceptive, since the beds below these next to be described belong to a very low portion of the subcretaceous series, and differ from all those seen between Lisbon and the coast: therefore there must be a break in the continuity of the series, either between the hippurite limestone and the ferruginous sands of Bucellas, or between these and the calcareous series below them; and the former is far more probable.

After passing Bucellas the section crosses lower beds of sand and marl with some alternations of limestone. Below these are beds of argillaceous limestone containing some corals, alternating with marl: these pass downwards into a series of beds of grey limestone of considerable thickness, and so full of corals as to suggest the idea that they were originally part of a great coral reef: at Trancozo de cima on the line of our section their dip is S.W. 20°: these limestone beds are one of the principal features in the geography of this district, as they form the crest of the steep ridge of hills extending to the N.W. from the south side of Albandra towards Sobral, on which were the principal defences of the lines of Torres Vedras.

Below the preceding are seen alternations of sand and sandstone with some beds of coralliferous limestone overlying a great thickness of ferruginous sands which cover a large space of flattish country near Aruda, and in which there are also some beds of sandstone, marl and limestone.

Below this arenaceous series lies a coarse white limestone which forms a saddle at Refugidos, and which is the lowest bed exposed on this line of section, and the lowest member of the subcretaceous series observed in Portugal. Yet from the irregular positions in which the beds of this series rest on the jurassic limestones, we cannot judge whether we have here really reached the bottom of the subcretaceous series.

I received a rich collection of fossils, through the kindness of Señor Edwardo Augusto Boaventura, from the limestone beds lying beyond Sobral towards Torres Vedras, which I believe to be the continuation of those seen on the last section at Trancozo de cima: it contains the following species, viz.:—

Cidaris clunifera, *Agassiz*.
Natica prælonga, *Deshayes*.
Nerinæa turbinata, n. s.
Artemis cordata, n. s.

Astarte discus, n. s.
Cardium dissimile, *Sow.*
Corbula Edwardi, n. s.
Cyprina securiformis, n. s.
Gervilia aviculoides, *Sow.*
—— Fittoni, n. s.
—— Sobralensis, n. s.
Mytilus Morrisii, n. s.
Ostræa pustulosa, n. s.
Pecten Lusitanicus, n. s.
Perna Lusitanica, n. s.
—— rugosa, *Goldfuss.*
Tellina Sobralensis, n. s.
Trigonia Lusitanica, n. s.
—— muricata, *Goldfuss*, sp.

The same gentleman sent me a fine specimen of *Sphæra corrugata* of Sowerby, from the sandstones of the same neighbourhood; this species has been republished by M. d'Orbigny under the name of *Corbis cordiformis*: it is a most characteristic shell of our greensand. The Portuguese specimen differs slightly in wanting the faint radiating lines seen on the English and French specimens, but is otherwise undistinguishable: this trifling difference will not constitute it a new species, as those lines vary much in our specimens.

Between Enxarra dos Cavalheiros and San Sebastian, in beds probably belonging to nearly the same part of the series, I found on a former excursion

Trigonia muricata, *Goldfuss*, sp. Perna Lusitanica, n. s.

The species in the above lists are so different from those found in the calcareous beds north of Cintra (p. 151), the only common species being *Natica prælonga*, that they show that the beds of the two localities belong to very different positions in the subcretaceous series.

From Refugidos through Alenquer to the northward, the section No. 5 (fig. 6) crosses the beds, just described, in the ascending order, dipping to the opposite direction of E.N.E. at angles varying from 10° to 20°: I examined this part of the section in greater detail than the former. For easier comparison let us begin at the east end of the section and thus adhere to the descending order as before. The uppermost bed seen on this line is a loose sand in the valley of Corregado, beyond which we cannot carry the series, as the subcretaceous beds are lost to the eastward for some miles in a broad marsh which probably conceals a line of fault.

Sandstones and sand of a light ferruginous colour, flanking the hills north of Villa Franca, lie next below the sands of Corregado, and are succeeded by the following:—

Coarse calcareous breccia, seen to the north of Alenquer.
Sand and sandstone with beds of micaceous flagstone, on the north side of Alenquer.
Calcareous sandstone.
Hard white compact limestone.
Calcareous conglomerate.
Coarse coralline limestone containing also some shells: it caps the hill of Alenquer. This is obviously the same bed as that crossed on the former part of the section at Trancozo de cima, and like that is a true coral reef; it is perhaps 150 feet thick.
Sand and sandstone, occasionally calcareous.
Red and variegated marls.

Thin-bedded sandy limestone with shells.
Sand and sandstone; at Verandas.
Sand and marl with some beds of limestone; at Carnota.
Coarse white limestone at Refugidos; the lowest bed of the section.

The following species were found in the limestone at Alenquer:—

Cidaris clunifera, *Agassiz*.
—— glandifera, *Goldfuss*.
Nerinæa annulata, n. s.
Nerinæa Bruntrutana, *Thurman*.
—— gigantea, *D'Hombres-Firmas*.
—— grandis, *Voltz*, not of *Goldfuss*.

The following were found in the calcareous beds below the Alenquer limestone, between two and three miles south of that town:—

Nerinæa turbinata, n. s.
Nerita turbinata, n. s.
Neritina bicornis, n. s.
Corbula compressa?, *D'Orbigny*.
Cyprina securiformis, n. s.
Perna polita, n. s.

We must refer to the same bed the two great ridges of coralline limestone crossed on section No. 5 (fig. 6), the more eastern of which runs northward from Villa Franca through Alenquer, passing a little west of Otta, and continuing to Alcoentre; the other commencing on the Tagus on the south side of Alhandra and forming the line of Wellington's defences to Sobral: their position, dipping in opposite directions away from a common axis, their identity of mineral character, and the similarity of their organic contents, which in both cases consist principally of corals of which several of the species are the same, all show the identity of these limestones. Therefore in looking at the fossils with the view of settling the age of the deposits, we may unite the above lists with those at p. 154, and consider the whole together.

The lists present us with a most unusual assemblage of shells; of which

Natica prælonga, *Deshayes*,
Sphæra corrugata, *Sow.*,
Nerinæa gigantea, *D'Hombres-Firmas*,
Corbula compressa, *D'Orbigny*,
Cidaris clunifera, *Agassiz*,

are only hitherto known in the lower greensand; and to these *Nerinæa turbinata* will probably have to be added as a greensand species.

Cardium dissimile, *Sow.*,
Gervilia aviculoides, *Sow.*,

have been found in England both in the lower greensand and in the Portland oolite.

Nerinæa Bruntrutana, *Thurman*,
Nerinæa grandis, *Voltz*, not of *Goldfuss*,

have been found in the Portland oolite.

Cidaris glandifera, *Goldfuss*,
Perna rugosa, *Goldfuss*,

usually belong to the great oolite.

Notwithstanding the admixture of oolitic species, those of the greensand predominate, and lead me to class these beds in the subcretaceous series. The position and character of the beds also are in favour of the same view. They agree so closely in mineral character and underlie in so regular a sequence the rest of the subcretaceous

rocks of the country, that it is quite uncertain where we ought to separate them; and no good line of distinction, either geographical or stratigraphical, has been observed between these beds and the calcareous series north of Cintra. In fact it was only after my return home, and when I had examined all the fossils, that I became aware of the marked difference of age between them. In all my rambles while in Portugal, it never occurred to me to draw any line between the two sets of beds.

On the other hand, these beds rest unconformably on the jurassic limestone of Monte Junto, and present a striking contrast to all the Portuguese rocks of the oolitic period. We must therefore conclude that the sandstones and limestone here described belong to the lowest member of the subcretaceous series, which, following closely after the jurassic system without any intervening break like that caused in the north of Europe by the intervention of the freshwater formation of the Wealden, contains a large admixture of oolitic species.

In comparing the Portuguese series of beds with that of England, we can find no parallels in England for the coralline limestone and associated beds of Alenquer and Torres Vedras, and must class the whole of this part of the series below our lower greensand, yet above our oolites, and thus perhaps as the marine contemporary of the Wealden formation. If the Neocomian beds of the south of France and Switzerland should hereafter be proved to be distinctly older than the lower greensand of the north, which appears probable, we must then refer these Portuguese beds to the Neocomian series: in the mean time I have avoided using the term Neocomian, lest the beds in question should be confounded with the lower greensand of England, Germany, and the north of France, to which that name has been sometimes unfortunately applied, and which is I think more modern than the Portuguese beds in question.

Jurassic Series of Beds*.

It has already been mentioned that the district covered by the subcretaceous beds is broken through in many places by limestones belonging to the Jurassic or Oolitic period which rise unconformably through the strata resting upon them. These jurassic rocks occur in different parts of the country, forming independent lines of hills, so that their relation to one another is nowhere seen, and their relative age can only be deduced from the comparison of their organic remains. It appears from such evidence that there are in Portugal equivalents of nearly all the principal members of the oolitic series. I will describe them in the order of their supposed age, beginning with the most modern.

Chain of Limestone from Monte Junto to the Mondego.

The Serra de Monte Junto, which lies nearly forty miles north by east of Lisbon, is the southern termination of a chain of limestone

* I use the term *Jurassic* in preference to *Oolitic*, because the limestones of Portugal have rarely an oolitic structure; and the latter term might lead to a misconstruction as to the mineral character of the beds in question.

hills about ninety miles long and rarely more than one or two miles broad, which extends from Monte Junto northwards nearly to the Mondego, a few miles below Coimbra. This chain does not cross the Mondego, but as I only followed it northward as far as the spot where it is crossed by the Lisbon road on the level of Condeixa, I cannot state its exact termination, which I presume to be on the southern bank of the Mondego.

The limestone at Monte Junto is about two miles wide and rises to the height of about 2000 feet*; the beds are thrown up irregularly at high angles and dip away from the centre of the hill on three sides, towards the east, south and west, at angles varying from 40° to 80°; while on the north they are broken off from the rest of the chain by a narrow ravine called the Ferradouro, which admits of the passage of a tolerable road through the chain. No intrusive rock is here visible, but the force which elevated this long chain appears to have acted with great intensity at this spot, while it was diminished farther south, where the jurassic beds are not raised to sight and the subcretaceous rocks are less disturbed. The section No. 6 (fig. 7) shows the position of the beds at Monte Junto: the effect produced at Alhandra, which is the most southern point to which this elevation can be traced, may be seen in section No. 4 (fig. 5) at p. 152.

Fig. 7.

Section No. 6. Across Monte Junto. (15 miles.)

The rock at Monte Junto is a hard, white or greyish argillaceous limestone with somewhat of a conchoidal fracture, and, in some of its beds, contains numerous *Ammonites* and fragments of *Encrinites* which are not easily to be extracted: among the specimens brought away I have identified the following species, from which we may infer that this limestone belongs to the upper part of the oolitic system:—

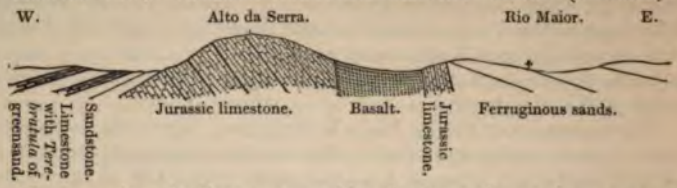
Ammonites Boucaultianus?, *D'Orbigny*.
—— colubrinus, *Reinecke*.
Ammonites polyplocus, *Reinecke*.
—— tortisulcatus, *D'Orbigny*.

From Monte Junto the limestone chain runs for about thirty-five miles N.N.E. to Carvalhos: the road usually followed from Lisbon to Coimbra (called the *Estrada nova*) runs on the east flank of the chain from Alcoentre to Rio Maior; after leaving the latter place the road inclines to the N.W. and crosses the chain at Alto da Serra, where the limestone is only about a mile broad and of inconsiderable elevation. The limestone beds here dip at angles of 60° to 70° to the eastward and are broken through by a mass of trap, as is shown in section No. 7 (fig. 8), and the jurassic limestone is overlaid unconformably on both sides by sands of the subcretaceous formation, which are elevated where they rest on the limestone to angles varying from 20° to 30°.

* There is an establishment at the top for collecting ice for the supply of Lisbon.

Fig. 8.

Section No. 7. Between Candieiros and Rio Maior. (5 miles.)



After crossing the limestone at Alto da Serra the road runs northward on the west flank of the chain for about twenty miles to Carvalhos, where the chain suddenly bends to the eastward. From Alto da Serra to Carvalhos the jurassic limestones dip eastward at angles varying from 30° upwards: the lowest beds seen are frequently somewhat oolitic and associated with a fine-grained calcareous sandstone, which forms a beautiful white freestone for architectural purposes, and has been used for the finest Gothic work in the church of Batalha: the middle and upper beds are of a hard, white or greyish argillaceous limestone like that of Monte Junto, occasionally containing fossils, which I had no opportunity of extracting. During this part of its range we nowhere see on what the limestone rests, and its western flank, on which its lower beds crop out, is always covered by unconformable deposits of subcretaceous beds. I did not see the eastern side of this part of the chain.

From Carvalhos the limestone chain suddenly turns eastward, passing by Porto de Moz and Aire; beyond the latter place it rises into a lofty range called the Serra d'Aire. I did not follow the limestone through this part of its course.

At the eastern end of the Serra d'Aire the limestone range again turns northward and runs about N. by W. for nearly twenty miles to Redinha; this part of the chain is less elevated and has not obtained a name, yet it forms a marked feature in the country. I crossed it at Val d'Ovos, about six miles from Thomar on the road to Leiria, and then after losing sight of it for some miles came upon it again before reaching Redinha, where the similarity of direction and general characters left me no doubt of the identity of the beds.

At Val d'Ovos the beds of limestone dip E.S.E. 10°, and cover a width of about a mile; the rock is a hard, white, compact limestone with a conchoidal fracture, and contains Belemnites, Turritellæ, Corals, &c., which I had not time to collect. On the western flank of the chain the limestone is seen to rest on a soft ferruginous sandstone containing minor beds of limestone; these lower beds are very little exposed, being overlaid to the westward by unconformable beds of subcretaceous sands dipping W. 3°. On the east of the chain the limestone is covered by a formation of ferruginous sands which appear conformable to it; these are described farther on. The position of the beds seen on this traverse will be seen in section No. 3 (fig. 4).

Near Redinha the limestone stretches out in an easterly direction, and rises again into a high mountain ridge called indifferently the

Serra de Rabacal or the Serra de Ancião* : the Lisbon road which had run parallel to the chain for some miles south of Redinha crosses the western prolongation of the limestone at that village: the beds dip N. 65°, and consist of a compact white limestone with a conchoidal fracture.

North of the Serra de Rabacal the limestone resumes its former course of N. by W.: the road to Coimbra, after keeping for five miles on its west flank, crosses the chain to Condeixa: the beds here strike N. and are nearly perpendicular; the limestone is divided by some thick intervening beds of ferruginous sandstone. The chain is here flanked on both sides by the sands of the subcretaceous series lying with slight inclination against the nearly perpendicular jurassic limestones.

To the northward of Condeixa the limestone chain gradually sinks down and loses its importance; I followed it no farther and cannot state its exact termination, but I ascertained on another trip that it is not to be seen on the north bank of the Mondego.

Throughout the long course of this limestone chain I was only fortunate enough to collect fossils at Monte Junto at its extreme termination southward; these indicate that the beds at that spot belong to the upper portion of the oolitic series: I think it probable that the rest of the chain belongs to the same part of the oolitic system, but this requires confirmation from farther observation.

I have only visited a small portion of the district which lies to the east of the great limestone chain just described, and must return to it before I can be certain of having seen all the secondary formations of this part of Portugal.

As has been already mentioned at p. 157, the southern end of the chain is encircled by the subcretaceous beds which flank its eastern side from Monte Junto to Rio Maior, beyond which I did not follow that side of the chain. The same occurs at the northern extremity of the chain, its eastern edge being overlaid at Condeixa by subcretaceous beds.

The middle part of the jurassic chain is overlaid near Thomar by beds whose age I cannot fix, as I found no organic remains in them, and cannot compare them with any of the beds seen on the west of this chain. Thomar stands on a thick formation of a softish, friable, white limestone, occasionally brecciated, and passing in its upper beds into a white calcareous sandstone: the dip at Thomar is E. 3°: I found no trace of organic remains in this rock. A limestone of similar mineral character and usually nearly horizontal, reaches from Thomar to Torres Novas and Pernes. About three miles west of Thomar the white limestone just described is seen to rest on soft ferruginous sandstone and sands, covering a band about three miles wide. This sandstone rests on the jurassic limestone of Val d'Ovos, which dips at the junction E.S.E. 10°, so that the three

* There is great confusion in the names of hills throughout Portugal, as the inhabitants of the opposite sides of a chain often give it different names, and those marked in the maps are frequently incorrect.

strata appear to follow conformably (see *ante* p. 158, and section No. 3, fig. 4). It might therefore be thought that we had here the regular succession of the beds above the jurassic limestone of Val d'Ovos, yet I can hardly believe this to be the case, because the limestone beds at Val d'Ovos are of less thickness than in many other parts of the chain, and their series may therefore be incomplete; and it is probable that if the Thomar beds were of an age immediately following on the jurassic limestone, they would more often be seen in connection with them.

On the other hand, I cannot connect the Thomar limestone with the subcretaceous series, since I have seen no fossils in it, and it differs in mineral character from all the subcretaceous limestones observed to the westward; and the sands below it have no peculiar character which can guide us in determining their age. We must therefore leave the determination of the age of these beds until more information is collected about them.

Limestone and Sandstone of Coimbra.

The city of Coimbra stands on a limestone formation of great thickness, which rises unconformably from below the beds of limestone and sandstone of the subcretaceous period, as previously described (p. 146), and shown in sections, Nos. 1 and 2 (figs. 2 & 3).

The upper beds of limestone are well seen at Fornos, three or four miles north of Coimbra, and again two or three miles to the south of the town on the Lisbon road; they consist of thin alternating beds of hard argillaceous limestone and marl. From below these rises a hard, compact, grey limestone of great thickness, dipping N.W. 30° to 45°, on which the town is built, and which extends for several miles on both sides of the river to the N.E. and S.E., forming nearly a semicircle. Organic remains must be rare, as I found no trace of them in several spots which I examined; but in the Museum of the University of Coimbra are a few Ammonites from the upper beds of the limestone at Fornos, which led me to suppose on a very slight examination that the limestone belongs to the upper or middle part of the oolitic series.

At the upper part of Coimbra the limestone is seen to rest conformably on a formation of ferruginous sandstone of very great thickness: the beds at the junction dip N.W. 30°.

The following is the order of the beds of the sandstone formation:—

1. Hard calcareous conglomerate lying below the Coimbra limestone; of little thickness.
2. Softer ferruginous sandstone with some beds of red and blue marls.
3. Ferruginous sands.
4. Ferruginous sandstone, containing numerous large blocks of indurated slate, jasper, &c.

Each of the three lower divisions is of great thickness, and the whole covers a breadth of about four miles, with a dip usually of N.W. 30°. The sandstone rests at Portella, four miles east of Coimbra, against a lofty ridge of micaceous schist which runs nearly north and south, and forms the eastern boundary of the secondary district.

Having only traced the Coimbra limestone and sandstone for a few miles from that city, I am not aware how far they extend either to the north or south. The Serra de Busaco has been described to me as consisting of a sandstone resting on micaceous schist, and as this range of hills is exactly on the line of the Coimbra sandstone, it is possible that the sandstone of Busaco may belong to the same formation, although some specimens from that locality in the Museum at Coimbra have a metamorphic appearance.

The limestone of Coimbra is separated from the jurassic limestone chain west of Condeixa by several miles of flat country covered by subcretaceous beds. Until the organic remains have been examined, it cannot be determined whether it is strictly identical with any of the other jurassic limestones of Portugal; it is however not improbable that the Coimbra sandstone may prove identical with the sandstone which near Buarcos overlies the carboniferous series of Cape Mondego, which belongs to the oolitic period and will be next described. Till this is ascertained, we must be content to class the Coimbra limestone and sandstone in the jurassic system without determining their exact place in the series.

Limestone and Coal of Cape Mondego.

It has been mentioned p. 147, that below the red sandstone of Buarcos, referred to the subcretaceous period, there is another bed of sandstone, of the oolitic period, connected with the coal and limestones of Cape Mondego: a good section of these beds is seen along the coast between Buarcos and the extremity of the Cape, exhibiting the following series in descending order:—

1. Red sandstones with some beds of marl, commencing a little west of Buarcos, where they dip E.S.E. 15°; farther west the dip is S.E. 40°. These sandstones appear to be the uppermost jurassic rocks seen in this neighbourhood.
2. A series of sandstones of various characters containing a few thin beds of impure limestone, which become more important in the lower portion.
3. Coarse limestone about 100 feet thick with some partings of sandstone with abundance of small oysters and other shells, dip S.E. 40°.
4. Sandstone of great thickness with some thin beds of limestone, containing Ostræa, Terebratula, &c., dip S.E. 40°; in the lower part the limestones are thicker and more frequent.
5. Carboniferous series, viz.:—

a. Alternate thin beds of marl, limestone and sandstone, 15 feet.
b. Coal, 2 feet.
c. Alternations of white limestone and grey marl, 12 feet.
d. Coal, 1 foot.
e. Marl and sandstone, 5 feet.
f. Coal, 6 inches.
g. Carbonaceous shale alternating with limestone, 6 feet.
h. Coal, 1 foot.
i. Alternations of shale and limestone, 8 feet.

j. Coal, 1 foot.
k. Grey marl, 3 feet.
l. Coal, 3½ to 4½ feet; the only bed worked.
m. Grey marl, 6 feet.
n. Alternation of grey marl and white limestone.

6. A formation of great thickness, consisting of thin beds of bluish earthy limestone alternating with blue marl, the beds varying from six inches to two feet thick; this series resembles in appearance our blue lias: dip S.E. 40°. These beds are crowded with Ammonites, some of which are above three feet in diameter, and other shells.

7. I did not see the beds underlying the above, but I was told that on the north side of the Cape a red marl rose from beneath them.

The organic remains found in the limestones Nos. 3 and 4, above the carboniferous series, are few in number, and of species which only serve to indicate the middle part of the oolitic series; they are as follows:

Corbula trigona, *Rœmer*.
Dianchora bicornis, n. s.
Mytilus Beirensis, n. s.
Ostræa solitaria, *Sow*.
Perna mytiloides, *Lam*.
Terebratula bisuffarcinata, *Schlotheim*.

There appear to be six beds of coal known, forming a total thickness of about ten feet; the quality is bituminous, but it contains a good deal of sulphur, which prevents its general consumption, and the mines have only been worked on a small scale: the mines are close to the sea, but the coast is too rough to allow the coal to be shipped on the spot, and it is carted to Figueira for shipment.

M. Michon, the director of the works, was kind enough to supply me with every information concerning them, and to give me some specimens of a *Zamites*, which was the only plant he had observed in the beds; it was found in the grey marl (*m*) immediately below the principal bed of coal. I could find no traces of any other plants among the rubbish of the mine.

Mr. Morris has had the goodness to examine the specimens, and finds it to be a variety of *Zamites gramineus*, a well-known species of the carboniferous shales associated with the inferior oolite on the coast of Yorkshire. His remarks on the subject will be found in the Appendix.

The following species were found in the beds of blue marl and limestone No. 6, below the coal series; they clearly prove that these beds belong to the lower part of the oolitic series:—

Terebratula Astieriana, *D'Orb*.
—— Beirensis, n. s.
—— decorata, *Von Buch*.
—— perovalis, *Sow*.
Ammonites anceps, *Reinecke*.
—— Bakeriæ, *Sow*.
—— Brongniartii, *Sow*.
—— discus, *Sow*.
—— hecticus, *Reinecke*.
Ammonites Henrici?, *D'Orb*.
—— Humphriesianus, *Sow*.
—— macrocephalus, *Schlotheim*.
—— modiolaris, *Luid*.
—— oolithicus, *D'Orb*.
—— plicomphalus, *Sow*.
——. Three species, supposed to be undescribed.

Perhaps on farther examination, the sandstones which lie above the coal series of Cape Mondego may prove to be identical with the red sandstones below the Coimbra limestone. This seems the most probable classification of these detached masses of jurassic rocks.

Limestone of Montemór-velho, &c.

The town of Montemór-velho, on the north bank of the Mondego, twelve or fifteen miles below Coimbra, stands on the southern extremity of a ridge of limestone about a mile wide running to the N.N.E., which is raised unconformably at a high inclination through the subcretaceous sandstone district (see section No. 2, fig. 3). At Montemór the limestone beds form a steep anticlinal axis; but this is merely local, as a little north of the town they all dip S.E. 30°, and further to the north E. 30°. The ridge is of moderate height and dies away gradually in its course northward.

The limestone is rather soft, white, and very argillaceous; it contains abundance of Ammonites, Belemnites, and other shells which prove it to be of the age of the lias: the following is the list:—

Gryphæa obliquata, *Sow.*
Plicatula spinosa, *Sow.*
Terebratula bidens, *Phillips.*
—— ornithocephala, *Sow.*
—— punctata, *Sow.*
—— tetrahedra, *Sow.*
Ammonites brevispina?, *Sow.*
—— Braunianus?, *D'Orb.*
Ammonites catenatus, *Sow.*
—— spinatus, *Bruguière.*
—— Stokesii, *Sow.*
—— Thouarensis?, *D'Orb.*
Belemnites paxillosus, *Schlotheim*
Nautilus truncatus, *Sow*
Turrilites Beirensis, n. s.

I only followed the limestone for four miles to the northward of Montemór, but in crossing from Aveiro to Coimbra, I observed a limestone of precisely similar mineral character at Vendas Novas, four leagues north-west of Coimbra: this place is about twenty miles N.N.E. of Montemór, and is consequently on the exact strike of the Montemór limestone; several fossil shells are common to the two localities, and the list of those found at Vendas Novas connects the limestone of that place with the lias. I feel convinced therefore that this is the northern prolongation of the Montemór ridge of limestone.

The following species were found at Vendas Novas:—

Plicatula spinosa, *Sow.*
Spirifer Beirensis, n. s.
—— granulosus, *Goldf.*
Terebratula tetrahedra, *Sow.*
—— carinata, *Lam.*
Ammonites spinatus, *Bruguière.*
—— Stokesii, *Sow.*
Belemnites exilis, *D'Orb.*
—— paxillosus, *Schlotheim.*

The beds at Vendas Novas dip S.E. 10°, and rise very little above the level of the surrounding subcretaceous beds, with which they might easily be confounded, if the organic remains were not carefully observed. Their position is shown in section No. 1 (fig. 2).

The prolongation of the line of the limestone to the N.N.E. would bring it across the road from Coimbra to Oporto near Agueda, but as I saw no trace of such limestone in that neighbourhood, I presume that beyond Vendas Novas it sinks below the subcretaceous beds.

There is however a patch of similar limestone at Mealhada on the Oporto road, about three leagues north of Coimbra: its characters are exactly similar to those of the limestones of Montemór and Vendas Novas, and like them it contains the *Belemnites paxillosus* in abundance, so that it is doubtlessly part of the same bed, though on a different line of strike.

The limestone of Mealhada is slightly exposed and its relations are not well seen: on the north and south it is soon covered up by the subcretaceous sands, but I did not see how far it extended in the other directions.

Limestone of San Pedro and Shale of Ramalhaõ, near Cintra.

These beds are described at p. 122 of my former paper on the Neighbourhood of Lisbon, where they are erroneously stated to be continued to the coast along the north side of the range of granite: this is not the case, as on that side of the hills they stop close to the town of Cintra, and the beds which overlie the granite between Cintra and the sea belong to the subcretaceous series.

In the shale at Ramalhaõ some organic remains occur, but usually in very bad condition, as the great masses of trap interstratified with the shale have altered its characters and almost reduced it to the condition of slate: the following were found by the side of the road close to Ramalhaõ:—

Ammonites, too much crushed for identification.
Pleurotomaria.
Avicula.
Posidonia Bronnii, *Goldf.* t. 113 f. 7.

The last is a species found in the lias of Wirtemburg, with which formation we must connect this bed until we have better evidence respecting it.

I have nothing to add to the former description of the San Pedro limestone; the only organic remains observed in it were amorphous masses apparently related to sponges, which are very abundant in the limestone a little to the north of San Pedro. The shells mentioned at p. 123 of the former paper belong to the subcretaceous limestones.

As the shale of Ramalhaõ overlies the San Pedro limestone conformably, it is probable that the latter also belongs to the period of the lias.

The preceding rocks are all the deposits north of the Tagus belonging to the oolitic series with which I am acquainted. I believe that the high limestone range of the Serra de Arrabida near St. Ubes will also prove to belong to the same series: but the limestone hills along the coast between Coimbra and Cape Espichel, formerly described as the Espichel limestone, belong with the rest of that formation to the subcretaceous series. (See *ante* p. 151, and Geology of Neighbourhood of Lisbon, p. 121.)

The preceding descriptions of the various isolated jurassic deposits of Portugal, coupled with the study of the organic remains contained in them, lead to the following comparison of these rocks with the oolitic series of England, viz.:—

The limestone of Monte Junto and subjacent sandstone are to be classed with the upper portion of the oolites.

The limestone of Coimbra, resting on a great thickness of red sands, will probably prove next to the above in the descending order.

The calcareous beds above the coal of Cape Mondego, surmounted by red sandstone, belong to the middle of the oolitic series.

The carboniferous beds of Cape Mondego must be compared to the oolitic coal of Yorkshire: their position in the series seems nearly the same, and the same species of *Zamites* has been found in both.

The beds of limestone and marl below the coal belong to the lower part of the oolitic series.

The limestones of Montemór-velho, Vendas Novas, and Mealhada must be classed with the lias.

In this list we seem to have representatives of the principal oolitic beds; yet it is probable that there are other jurassic beds in the Peninsula which have no representatives in the district here described; for it has been usual to class in the oolitic system the grey limestone of Gibraltar and the Ronda hills which rests on a thick formation of brown shale, neither of which rocks can be compared with any of the beds above mentioned. The limestone of San Pedro near Cintra has more resemblance in mineral character to that of Gibraltar than any other of the Portuguese limestones, but it would be premature to class them together while so little is known of either.

This comparison of the jurassic rocks of Portugal with those of England is only made in the most general sense: the rocks of the two countries differ in mineral character, being in England oolites alternating with blue clays, and in Portugal hard compact limestones separated by ferruginous sands: it is only in the organic remains contained in them that we find any true resemblance.

Sandstones of which the age is not yet determined.

To complete the account of my observations of the secondary formations of this part of Portugal, it only remains to describe certain beds of sandstone of undetermined age, which lie within the area of secondary rocks.

Red Sandstone of the Vouga.—Following the road from Coimbra to Oporto we meet near Agueda with a coarse, friable, white sandstone dipping S.E. 5°, which passes into a softer reddish sandstone and ferruginous sand which continue to within a quarter of a mile of Serdaõ, where they dip S. 2° or 3°; these are the last beds of the subcretaceous series which are seen in proceeding northward along this road.

Just before reaching Serdaõ, a red sandstone, dipping S. 15°, rises from below the beds just mentioned and continues with some irregularities of dip to the north bank of the Vouga, where its continuation to the northward is concealed by gravel covering the country up to the appearance of the micaceous schist at Albergaria velha.

The red sandstone of Serdaõ has no resemblance to any of the Portuguese rocks yet described; it is a fine-grained sandstone of a deep brick-colour, in well-defined beds separated by thin layers of marl, and closely resembles the new red sandstone of our Midland counties. It cannot extend far to the westward of Serdaõ, as near the mouth of the Vouga the subcretaceous sands rest immediately on the Silurian rocks. I have no information respecting its extent eastward, and must leave its age in doubt. Yet its position in contact with the older schists being similar to that of the sandstones of Busaco and

Coimbra, makes it probable that these sandstones may belong to the same period and form the outer line of secondary rocks. But the different mineral character of these deposits is against the supposition.

There are still several parts of the district north of the Tagus which must be explored, before the series of the secondary formations of that part of Portugal can be considered complete. The narrow line of country between the schists of the Deuça and Zezere and the jurassic chain of Monte Junto, the Serra d'Aire, &c., must be fully examined to establish the connection between the limestone of Thomar and the other formations described. The south bank of the Mondego must also be examined, as we may there hope to find some connecting links between the various members of the jurassic series. And the boundary of the secondary district north of Coimbra must be visited, to determine whether any connection exists between the sandstones of Serdaõ, Busaco, and Coimbra. Until these spots have been visited, the map here offered of the northern half of Portugal can only be regarded as a rough approximation.

General Remarks.

Throughout the district here described there is less variety of mineral character than are usually seen in the same range of formations; the whole consisting almost entirely either of ferruginous sand and sandstone or of compact limestone, with very little clay or shale. The sands, whether of the tertiary, the cretaceous, or the oolitic periods, have all nearly the same characters, and can hardly be distinguished by their appearance, and most of the limestones of the cretaceous, subcretaceous, and jurassic formations have a similar compact structure, white colour, and conchoidal fracture. These resemblances between beds of different ages add to the difficulty of the first geological survey of the country, and might be pleaded in excuse for many errors; but they are also in themselves facts of interest, which show that the Portuguese rocks were deposited under conditions which varied little during long periods: some of these conditions may be ascertained from the comparison of the characters of the rocks and of the animals which have been entombed in them.

To commence with the lower beds: the fine-grained, argillaceous limestones of Montemór, Vendas Novas and Mealhada, referred to the age of the lias, seem to have been deposited in deep, quiet water: *Ammonites* and *Belemnites* are abundant in them, *Brachiopoda* are also common, but the *Lamellibranchiata* are rare, and I only met with one solitary *Gasteropod* of the genus *Pleurotomaria*.

The calcareous series below the coal at Cape Mondego has also the characters of a deep-water formation: the limestones are argillaceous and alternate with fine marls; the fossils found in them were *Terebratulæ* and *Cephalopoda*, the *Ammonites* being in extraordinary abundance.

The change from the beds just mentioned to the carboniferous series resting on them is so sudden, that it must be attributed to the upheaval of the bed of the sea soon after the deposition of the Cape

Mondego limestone, as we rise from limestones and marls full of *Ammonites* to a series of marls and sandstones, including several beds of coal and containing land plants, but without any remains of marine animals. And in the beds above this carboniferous series the organic remains present a complete contrast to those seen in the beds below the coal, being of the genera *Ostræa*, *Perna*, *Dianchora*, *Corbula*, and *Mytilus*, all probably inhabitants of moderate depths, with only one species of *Terebratula* and no *Cephalopod* whatever. To these succeed coarse sands and grits, which, like the *Mollusca* just mentioned, indicate the existence of a shallow sea at a moderate distance from land. And this is the character of all the subsequent deposits, excepting the great calcareous formations of Coimbra and Monte Junto, containing *Ammonites* and *Belemnites*, which were probably formed in deeper water.

The whole of the rocks of the subcretaceous series appear to have been formed near the land and in shallow water. The limestones in this series bear only a small proportion to the sandstones. In the lower division there are large accumulations of corals, which are so abundant at Alenquer and in the corresponding beds between Alhandra and Sobral as to form complete reefs: the species of *Ostraceæ*, *Cardium*, *Mytilus*, &c., together with *Gasteropoda* often of large size, also indicate deposits in seas of moderate depth, and the bed of lignite found in several localities proves that land was then not far distant. The negative evidence is to the same effect; in these beds I only found one specimen of *Belemnite* and not a single *Ammonite*, while the *Terebratulæ* are very rare and confined to the lower part of the series.

The hippurite limestone with subordinate beds of calcareous marl appears to have been formed in quieter water, but the organic remains found in it indicate that it was deposited in a sea of moderate depth: they are principally *Lamellibranchiata*, *Gasteropoda*, and *Rudista*, without any *Cephalopoda* or *Brachiopoda*.

Thus after the deposition of the older jurassic limestones nearly all the secondary rocks of this district appear to have been deposited in shallow waters, and for the most part in rough seas near a coast. But we cannot appreciate all the bearings of these facts till we know the characters of the formations of the same age in other parts of the Peninsula.

The proportion between the new and the previously known species of organic remains is very different in the different secondary formations of Portugal: in my collection only about 45 per cent. of the fossils from the hippurite limestone are described species, in the subcretaceous beds 53 per cent., and in the jurassic series about 84 per cent. As the species of secondary European fossils hitherto described are nearly all from the north and middle of Europe, the proportion of described species in a Portuguese formation shows how many of the species are known to have been common to the seas of the north and south of the Pyrenees at the geological epoch in question.

Before we can safely conclude from the above statement that the

inhabitants of the earlier seas had a wider range north and south than those of later periods, we must take into consideration the habits of the animals of which we find the remains, and see whether the differences are due to greater powers of migration of the species of one formation over those of others; or whether they depend on the different depths below the surface at which the shells may be supposed to have been originally deposited; for we may expect to find most widely diffused the remains both of animals capable of swimming out to sea and of the inhabitants of deep water, which being less affected by climate than those living near the coast, can live equally in very different latitudes.

The following table shows the number of the previously described and of the new species of the four orders of Mollusks, which include most of the Portuguese secondary fossils, in each division of the geological series; and also the proportion per cent. which the previously known species bear to the whole in each case.

	Known species.	New species.	Per centage of known species.
In the Hippurite limestone:—			
Gasteropoda	1	4	20
Lamellibranchiata	9	13	41
Brachiopoda	—	—	—
Cephalopoda	—	—	—
In the Subcretaceous series:—			
Gasteropoda	11	18	38
Lamellibranchiata	23	18	56
Brachiopoda	2	—	100
Cephalopoda	—	—	—
In the Jurassic series:—			
Gasteropoda	—	—	—
Lamellibranchiata	6	2	75
Brachiopoda	10	2	83
Cephalopoda	24	4	86
Total	86	61	

If we disregard the formations and look only to the character of the animals, we shall find that of the Portuguese specimens collected,

30 per cent. of the Gasteropoda,
54 „ „ „ Lamellibranchiata,
86 „ „ „ Brachiopoda,
86 „ „ „ Cephalopoda,

are known to the north of the Pyrenees: thus it appears that the swimming Cephalopods and the Brachiopods are diffused equally widely, which can only be attributed to the latter living at great depths. The Gasteropods prove to be the most local, which is doubtless due to their mostly living near the shore. The Lamellibranchs, which include species confined to the coast with others living at greater depths, hold an intermediate place in the scale. It is also to be remarked that the Brachiopods and Cephalopods are found in company and almost by themselves in the jurassic deposits; while in the cretaceous and subcretacous beds, in which Gasteropods and Lamellibranchs are abundant, the two former orders are almost rely wanting.

It seems from this analysis that the different depth of water under which the beds were formed has been one principal cause of the different proportions in which we find northern species entombed in the Portuguese formations. Yet after making every allowance on that head, there seems to have been a somewhat greater power of migration in the earlier periods, as the known species of Lamellibranchs are proportionally more numerous in the jurassic than in the subcretaceous beds, and in these than in the hippurite limestone, and the known Gasteropods of the subcretaceous beds are proportionally almost twice as numerous as those of the hippurite limestone.

I have dwelt at some length upon these speculations, because I believe that this is the first time that any large collection of secondary fossils from so southern a part of Europe has afforded the opportunity of comparing the inhabitants of the southern seas of the secondary periods with those of the secondary seas of our latitudes. The secondary collections hitherto made in Europe extend over many degrees of longitude, but have been very limited in latitude, and have therefore come from countries with moderate differences of climate.

I cannot conclude without expressing how much I am indebted to Mr. Morris for the assistance he has given me in the examination of the whole of my collection of fossils, and to Mr. Edward Forbes for his kindness in examining and describing the Echinodermata brought from the beds here described.

APPENDIX.

General List of the Organic Remains found in the Secondary Strata of Portugal.

Genus and Species.	References.	Formations.	Localities.
	PLANTÆ.		
ZAMITES			
gramineus, var. Mundæ.	Phillips, sp. Geol. Yorksh. vol. i. t. 10. f. 2; *post*, t. 26. f. 7.	Jurassic	Cape Mondego.
	ECHINODERMATA.		
BRISSUS			
subdepressus ...	Forbes, t. 25. f. 6.	Subcretaceous	Figueira.
scutiger	Forbes, t. 25. f. 5.	Hippurite limestone .	Near Lisbon.
CIDARIS			
clunifera	Agassiz, Echinod. de la Suisse, t. 21. f. 19–22.	Subcretaceous.....	Alenquer; near Sobral.
glandifera	Goldfuss, t. 40. f. 3	Subcretaceous.....	Alenquer.
læviuscula	Agassiz, Echinod. de la Suisse, t. 21. f. 18–20.	Subcretaceous.....	Figueira.
DIADEMA			
Lusitanicum ...	Forbes, t. 25. f. 4.	Subcretaceous.....	Mamarosa.
rude.....	Forbes, t. 25. f. 3.	Subcretaceous.....	Praia de Maçams.
ECHINUS			
Olisiponensis ...	Forbes, t. 25. f. 1.	Hippurite limestone .	Near Lisbon.
ECHINOPSIS			
subuculus	Forbes, t. 25. f. 2.	Subcretaceous.....	Figueira.
TOXASTER			
Couloni?	Agassiz	Subcretaceous.....	Figueira.
	CONCHIFERA.		
ANOMIA			
convexa	Sowerby, Geol. Trans., 2nd Series, vol. iv. t. 14. f. 7.	Hippurite limestone . Subcretaceous.....	Papel. Praia de Maçams.
lævigata	Sowerby, Geol. Trans., 2nd Series, vol. iv. t. 14. f. 6; d'Orbigny, Pal. Franç. T. Crét. t. 489. f. 4–6.	Subcretaceous.....	Praia de Maçams.
ARCA			
Moutoniana.....	d'Orbigny, Paléont. Franç. T. Crét. t. 321.	Hippurite limestone .	Papel; Lisbon.
Olisiponensis ...	n. s., t. 14. f. 1.	Hippurite limestone .	Lisbon.
Passyana?	d'Orbigny, Paléont. Franç. T. Crét. t. 327. f. 1–2.	Hippurite limestone .	Lisbon.
ARTEMIS			
cordata	n. s., t. 21. f. 3.	Subcretaceous.....	Near Sobral.
elegantula	n. s., t. 14. f. 2.	Hippurite limestone .	Papel.
inelegans.....	n. s., t. 20. f. 3.	Subcretaceous.....	Praia de Maçams.
ASTARTE			
discus	n. s., t. 21. f. 4 & 5.	Subcretaceous.....	Near Sobral.
AVICULA			
Olisiponensis ...	n. s., t. 18. f. 3.	Hippurite limestone .	Lisbon.
CAPRINULA			
brevis	n. s., t. 17. f. 1 & 2.	Hippurite limestone .	Lisbon.
Boissyi.....	d'Orbigny, Paléont. Franç. T. Crét. t. 540. *post*, t. 16.	Hippurite limestone .	Lisbon.

Genus and Species.	References.	Formations.	Localities.
CAPRINULA (*continued*).			
d'Orbignii	n. s., t. 18. f. 1 & 2.	Hippurite limestone .	Lisbon.
Doublieri.....	*Caprinella*, sp. d'Orb. Pal. Franç. T. Crét. t. 541. *post*, t. 17. f. 3 & 4.	Hippurite limestone .	Lisbon.
CARDIUM			
corrugatum	n. s., t. 14. f. 3.	Hippurite limestone .	Lisbon; Bucellas.
		Subcretaceous.....	Fontanellas.
dissimile ?	Sowerby, Min. Con. t. 553. f. 2.	Subcretaceous.....	Near Sobral.
Olisiponense ...	n. s., t. 14. f. 4	Hippurite limestone .	Lisbon.
CORBULA			
carinata	d'Orbigny, Pal. Franç. T. Crét. t. 388. f. 3–5.	Subcretaceous.....	Near Leiria.
compressa	d'Orbigny, Pal. Franç. T. Crét. t. 388. f. 6–8.	Subcretaceous.....	Near Alenquer.
Costæ	n. s., t. 20. f. 2	Subcretaceous.....	San Pedro de Muriel.
Edwardi	n. s., t. 21. f. 2	Subcretaceous.....	Near Sobral.
trigona.....	Rœmer, Oolith. t. 8. f. 5 ..	Jurassic	Cape Mondego.
CYPRINA			
cordata	n. s., t. 15. f. 2	Hippurite limestone .	Lisbon.
globosa	n. s., t. 15. f. 1	Hippurite limestone .	Lisbon.
securiformis.....	n. s., t. 22. f. 1–3	Subcretaceous.....	Near Sobral; Alenquer.
DIANCHORA			
bicornis	n. s., t. 26. f. 4 & 5.....	Jurassic	Cape Mondego.
DICERAS			
Favri	n. s., t. 15. f. 3. and t. 20. f. 9.	Hippurite limestone .	Lisbon.
		Subcretaceous.....	Praia de Maçams.
EXOGYRA			
conica	Sowerby, Min. Con. t. 605. f. 1–3.	Subcretaceous.....	Mamarosa; Sarjento-mór; San Sylvestre; Figueira.
Olisiponensis ...	n. s., t. 19. f. 1. & 2.	Hippurite limestone .	Lisbon.
plicata	Lamarck	Hippurite limestone .	Lisbon; Papel.
		Subcretaceous.....	Praia de Maçams; Ourem.
GERVILIA			
aviculoides	Sowerby, Min. Con. t. 511 .	Subcretaceous.....	Near Sobral.
Fittoni.....	n. s., t. 23. f. 3–6.	Subcretaceous.....	Near Sobral.
Sobralensis	n. s., t. 23. f. 1 & 2.	Subcretaceous.....	Near Sobral.
GRYPHÆA			
columba	Lamarck	Subcretaceous.....	Figueira.
obliquata.....	Sowerby, Min. Con. t. 112. f. 3.	Jurassic	Montemór.
ISOCARDIA			
cretacea ?.....	Goldfuss, t. 141. f. 1	Hippurite limestone .	Lisbon.
LITHODOMUS			
prælongus	d'Orbigny, Pal. Franç. T. Crét. t. 344. f. 1–3.	Subcretaceous.....	Aljubarrota.
MYTILUS			
Beirensis	n. s., t. 26. f. 1.	Jurassic	Cape Mondego.
Morrisii	n. s., t. 22. f. 5.	Subcretaceous.....	Near Sobral.
ornatus	d'Orbigny, Pal. Franç. T. Crét. t. 342. f. 10–12.	Subcretaceous.....	Ourem.

Genus and Species.	References.	Formations.	Localities.
OSTRÆA			
globosa	Sowerby, sp., Min. Con. t. 392; *vesicularis*, Goldfuss, t. 81. f. 2.	Hippurite limestone	Lisbon.
colubrina	Lamarck; Goldfuss, t. 74. f. 5.	Subcretaceous	Praia de Adrarga.
prælonga	n. s., t. 20. f. 4.	Subcretaceous	Praia de Maçams.
pustulosa	n. s., t. 24. f. 4.	Subcretaceous	Near Sobral.
solitaria	Sowerby, Min. Con. t. 468. f. 1.	Jurassic	Cape Mondego.
PECTEN			
æquicostatus	Lamarck; d'Orbigny, Pal. Franç. T. Crét. t. 445. f. 1–4.	Subcretaceous	Sarjento-mór.
Dutemplei	d'Orbigny, sp., Pal. Franç. T. Crét. t. 447. f. 8–11.	Subcretaceous	Figueira.
inconstans	n. s., t. 19. f. 3.	Hippurite limestone	Lisbon.
Lusitanicus	n. s., t. 24. f. 3.	Subcretaceous	Near Sobral.
quinquecostatus	Sowerby, Min. Con. t. 56. f. 4–8.	Subcretaceous	Praia de Maçams; Mamarosa.
striatocostatus	Goldfuss, t. 93. f. 2; d'Orbigny, sp., Pal. Franç. T. Crét. t. 449. f. 5–9.	Hippurite limestone Subcretaceous	Lisbon. Praia de Adrarga.
PERNA			
fragilis	n. s., t. 18. f. 4.	Hippurite limestone	Lisbon.
lanceolata	Geinitz; d'Orbigny, Pal. Franç. T. Crét. t. 402. f. 1–3.	Subcretaceous	Aljubarrota.
Lusitanica	n. s., t. 23. f. 7 & 8.	Subcretaceous	Near Sobral; near Enxarra.
mytiloides	Lamarck	Jurassic	Cape Mondego.
polita	n. s., t. 24. f. 1 & 2.	Subcretaceous	Near Alenquer.
rugosa	Goldfuss, t. 108. f. 2	Subcretaceous	Near Leiria; near Sobral.
PHOLADOMYA			
Ligeriensis	d'Orbigny, Pal. Franç. T. Crét. t. 363. f. 8–9.	Hippurite limestone	Lisbon.
Royana	d'Orbigny, Pal. Franç. T. Crét. t. 367.	Subcretaceous	Praia de Lagoa.
PLICATULA			
pectenoides	Sowerby, Min. Con. t. 409. f. 1.	Subcretaceous	Sarjento-mór.
spinosa	Sowerby, Min. Con. t. 245.	Jurassic	Vendas Novas; Montemór.
POSIDONIA			
Bronnii	Goldfuss, t. 113. f. 7	Jurassic	Ramalhao.
SPHÆRA			
corrugata	Sowerby, Min. Con. t. 335; *Corbis cordiformis*, d'Or. Paléont. Franç. T. Crét. vol. iii. t. 279.	Subcretaceous	Near Sobral.
TELLINA			
Sobralensis	n. s., t. 21. f. 1	Subcretaceous	Near Sobral.
TRIGONIA			
caudata	Agassiz, Trigon. t. 7. f. 1–3; d'Orbigny, Pal. Franç. T. Crét. t. 287; *scabra*, Morris, Catal.	Subcretaceous	Praia de Adrarga.

Genus and Species.	References.	Formations.	Localities.
TRIGONIA (*continued*).			
Lusitanica	n. s., t. 22. f. 4	Subcretaceous.....	Near Sobral.
muricata	Goldfuss, sp., t. 137. f. 1...	Subcretaceous.....	Near Enxarra ; near Sobral.
	BRACHIOPODA.		
SPIRIFER			
Beirensis	n. s., t. 26. f. 2	Jurassic	Vendas Novas.
granulosus	Goldfuss	Jurassic	Vendas Novas.
TEREBRATULA			
Astieriana	d'Orbigny, sp., Pal. Franç. T. Crét. t. 492. f. 1.	Jurassic	Cape Mondego.
Beirensis	n. s., t. 26. f. 3	Jurassic	Cape Mondego.
bidens	Phillips, Geol. Yorksh. vol. i. t. 13. f. 24.	Jurassic	Montemór.
bisuffarcinata ...	Schlotheim ; Zieten, Verst. Wurtemb. t. 40. f. 3.	Jurassic	Cape Mondego.
carinata	Lamarck	Jurassic	Vendas Novas.
Carteroniana ...	d'Orbigny, Pal. Franç. T. Crét. t. 507. f. 1–5.	Subcretaceous.....	Ericeira.
decorata	Von Buch; Bronn, Lethæa, t. 30. f. 12 ; *oxyopticha*, Fischer; d'Orbigny, Russie, t. 42. f. 11–13.	Jurassic	Cape Mondego.
Moutoniana.....	d'Orbigny, Pal. Franç. T. Crét. t. 510. f. 1–5.	Subcretaceous.....	Candieros.
ornithocephala...	Sowerby, Min. Con. t. 101. f. 1–4.	Jurassic	Montemór.
perovalis	Sowerby, Min. Con. t. 436. f. 2–3.	Jurassic	Cape Mondego.
punctata	Sowerby, Min. Con. t. 15. f. 4.	Jurassic	Montemór.
tetrahedra	Sowerby, Min. Con. t. 83. f. 4.	Jurassic	Montemór; Vendas Novas.
	GASTEROPODA.		
NATICA			
bulimoides	DesHayes, sp., d'Orbigny, Pal. Franç. T. Crét. t. 172. f. 2–3.	Subcretaceous.....	Sarjento-mór.
Dupinii	Des Hayes; d'Orbigny, Pal. Franç. T. Crét. t. 173. f. 5–6.	Subcretaceous.....	Near Pombal.
Lusitanica	n. s., t. 24. f. 5	Subcretaceous.....	Near Alenquer.
prælonga	Des Hayes ; d'Orbigny, Pal. Franç. T. Crét. t. 172. f. 1.	Subcretaceous.....	Near Sobral; Praia de Lagoa.
NERINÆA			
annulata	Sharpe, *ante*, t. 13. f. 1 ...	Subcretaceous.....	Alenquer.
Archimedis	d'Orbigny, Pal. Franç. T. Crét. t. 158. f. 3.	Subcretaceous.....	Praia de Adrarga.
Bruntrutana ...	Thurman; Voltz, Jahrb. 1836, t. 6. f. 13 ; Goldfuss, t. 175. f. 5.	Subcretaceous.....	Alenquer.
Conimbrica	Sharpe, *ante*, t. 13. f. 4 ...	Subcretaceous.....	Sarjento-mór.

Genus and Species.	References.	Formations.	Localities.
NERINÆA (*continued*).			
cylindrica	Voltz, Jahrb. 1836, t. 6. f. 16.	Subcretaceous	Praia de Adrarga; Sarjento-mór.
Eschwegii	Sharpe, *ante*, t. 13. f. 2	Hippurite limestone	Lisbon.
gigantea	d'Hombres-Firmas; d'Orbigny, Pal. Franç. T. Crét. t. 158. f. 1–2.	Subcretaceous	Alenquer.
grandis	Voltz, Jahrb. 1836, t. 6. f. 1; not of Goldfuss.	Subcretaceous	Alenquer.
nobilis	Goldfuss, t. 176. f. 9; Sharpe, *ante*, t. 12. f. 1.	Hippurite limestone	Lisbon.
Olisiponensis	Sharpe, *ante*, t. 13. f. 3	Hippurite limestone Subcretaceous	Lisbon. Praia de Maçams.
Titan	Sharpe, *ante*, t. 12. f. 3	Subcretaceous	Praia de Maçams.
turbinata	Sharpe, *ante*, t. 12. f. 2	Subcretaceous	Alenquer; near Sobral.
NERITA			
turbinata	n. s., t. 24. f. 6.	Subcretaceous	Alenquer.
NERITINA			
bicornis	n. s., t. 24. f. 7.	Subcretaceous	Alenquer.
PYRAMIDELLA			
sagittata	n. s., t. 20. f. 8.	Subcretaceous	Praia de Adrarga.
ROSTELLARIA			
Costæ	n. s., t. 20. f. 1.	Subcretaceous	San Pedro de Muriel.
TEREBRA			
obconica	n. s., t. 20. f. 5.	Subcretaceous	Cape Espichel.
TURBO			
Mundæ	n. s., t. 20. f. 7.	Subcretaceous	Figueira.
TURRITELLA			
Cintrana	n. s., t. 20. f. 6.	Subcretaceous	Praia de Maçams.
Renauxiana	d'Orbigny, Pal. Franç. T. Crét. t. 152. f. 1–4.	Subcretaceous	Praia de Maçams.
Vibrayana	d'Orbigny, Pal. Franç. T. Crét. t. 151. f. 10–12.	Subcretaceous	Figueira.
TYLOSTOMA			
globosum	Sharpe, Journ. Geol. Soc. vol. v. t. 9. f. 5–6.	Hippurite limestone Subcretaceous.	Lisbon. Sarjento-mór; San Fagundo.
ovatum	Sharpe, Journ. Geol. Soc. vol. v. t. 9. f. 7–8.	Hippurite limestone Subcretaceous	Lisbon. Sarjento-mór; Condeixa; San Fagundo.
punctatum	Sharpe, Journ. Geol. Soc. vol. v. t. 9. f. 3–4.	Subcretaceous	Sarjento-mór.
Torrubiæ	Sharpe, Journ. Geol. Soc. vol. v. t. 9. f. 1–2.	Subcretaceous	Condeixa; San Fagundo; Figueira.
	CEPHALOPODA.		
AMMONITES			
anceps	Reinecke, sp.; d'Orbigny, Pal. Franç. T. Jurass. t. 166 & 167.	Jurassic	Cape Mondego.
Bakeriæ	Sowerby, Min. Con. t. 570. f. 1–2; d'Orbigny, Pal. Franç. T. Jurass. t. 149. f. 1, not t. 148.	Jurassic	Cape Mondego.

Genus and Species.	References.	Formations.	Localities.
AMMONITES (*continued*).			
Boucaultianus ? .	d'Orbigny, Pal. Franç. T. Jurass. t. 90.	Jurassic	Monte Junto.
Braunianus	d'Orbigny, Pal. Franç. T. Jurass. t. 104. f. 1–3.	Jurassic	Montemór.
brevispina	Sowerby, Min. Con. t. 556. f. 2; d'Orbigny, Pal. Franç. T. Jurass. f. 79.	Jurassic	Montemór.
Brongniartii.....	Sowerby, Min. Con. vol. ii. p. 189. t. A. f. 3; d'Orbigny, Pal. Franç. T. Jurass. t. 137.	Jurassic	Cape Mondego.
catenatus.....	Sowerby ap. De la Beche, Traité de Géol. p. 407. f. 67; d'Orbigny, Pal. Franç. T. Jurass. t. 94.	Jurassic	Montemór.
colubrinus	Reinecke, 92; Quenstedt, t. 12. f. 10 *a* & *b*.	Jurassic	Monte Junto.
discus	Sowerby, Min. Con. t. 12; d'Orbigny, Pal. Franç. T. Jurass. t. 131.	Jurassic	Cape Mondego.
hecticus	Reinecke; d'Orbigny, Pal. Franç. T. Jurass. t. 152.	Jurassic	Cape Mondego.
Henrici	d'Orbigny, Pal. Franç. T. Jurass. t. 198. f. 1.	Jurassic	Cape Mondego.
Humphriesianus.	Sowerby, Min. Con. t. 500. f. 1; d'Orbigny, Pal. Franç. T. Jurass. t. 133–135. f. 1.	Jurassic	Cape Mondego.
macrocephalus...	Schlotheim; d'Orbigny, Pal. Franç. T. Jurass. t. 151.	Jurassic	Cape Mondego.
modiolaris	Luid, sp.; d'Orbigny, Pal. Franç. T. Jurass. t. 170; *A. sublævis*, Sow. Min. Con. t. 54.	Jurassic	Cape Mondego.
Oolithicus	d'Orbigny, Pal. Franç. T. Jurass. t. 126. f. 1–4.	Jurassic	Cape Mondego.
plicomphalus ...	Sowerby, Min. Con. t. 404; *Bakeriæ*, d'Orbigny, Pal. Franç. T. Jurass. t. 148; not t. 149.	Jurassic	Cape Mondego.
polyplocus	Reinecke; *planulatus*, Zieten, Verst. Wurtemb. t. 8. f. 1, 4, 7, 8, t. 9. f. 1.	Jurassic	Monte Junto.
spinatus	Bruguière; d'Orbigny, Pal. Franç. T. Jurass. t. 52.	Jurassic	Montemór; Vendas Novas.
Stokesii	Sowerby, Min. Con. t. 191; *margaritatus*, d'Orbigny, Pal. Franç. T. Jurass. t. 67 & 68.	Jurassic	Montemór; Vendas Novas.
Thouarensis.....	d'Orbigny, Pal. Franç. T. Jurass. t. 57.	Jurassic	Montemór.
tortisulcatus ...	d'Orbigny, Pal. Franç. T. Jurass. t. 189.	Jurassic	Monte Junto.

Genus and Species.	References.	Formations.	Localities.
BELEMNITELLA			
a fragment	.....	Subcretaceous	Alenquer.
BELEMNITES			
exilis	d'Orbigny, Pal. Franç. T. Jurass. t. 11. f. 6.	Jurassic	Vendas Novas.
paxillosus.....	Schlotheim; *Bruguieria-nus*, d'Orbigny, Pal. Franç. T. Jurass. t. 7. f. 1–5.	Jurassic	Montemór; Vendas Novas; Mealhada.
NAUTILUS			
truncatus.....	Sowerby, Min. Con. t. 123.	Jurassic	Montemór.
TURRILITES			
Beirensis	n. s., t. 26. f. 6.	Jurassic	Montemór.
	RUDISTA.		
SPHÆRULITES			
angeiodes	Lamarck; d'Orbigny, Pal. Franç. T. Crét. t. 549.	Hippurite limestone .	Lisbon.
cylindracea	Des Moulins, Essai sur les Sphéralites, t. 4. f. 1–3.	Hippurite limestone .	Lisbon.
Marticensis? ...	d'Orbigny, sp. Pal. Franç. T. Crét. t. 543. f. 4 & 5.	Subcretaceous.....	Praia de Maçams.
Ponsiana	d'Orbigny, Pal. Franç. T. Crét. t. 552.	Hippurite limestone .	Lisbon.
Sauvagesii	d'Orbigny, Pal. Franç. T. Crét. t. 553.	Hippurite limestone .	Lisbon.
ventricosa	Lamarck	Hippurite limestone .	Pero Pinheiro, Lisbon.

ARCA OLISIPONENSIS, n. s. PL. XIV. fig. 1 *a*, 1 *b*, & 1 *c*.

Shell gibbose, subtrapezoidal, divided into two unequal parts by a broad rounded keel extending from the umbo to the produced posterior angle, the anterior part gibbose and rounded, the posterior flat and sloping down to the straight and slightly oblique posterior margin. Ventral margin slightly rounded. Beaks near each other; hinge-area small.

Surface decussated with nearly equal, fine, radiating and concentric lines, with impressed elongated points at each intersection.

Length 2¼ inches; breadth 3 inches; thickness 2 inches.

Abundant in the upper beds of the hippurite limestone on the west side of Lisbon.

This species is nearly related to *A. Guerangeri*, D'Orb., but has a less rounded margin, a flatter posterior slope and closer concentric lines, producing a more regular decussation over the surface. Most of the specimens found are internal casts, but one of them shows a portion of the outer shell, which appears to have been thin.

PLATE XIV. fig. 1 *a*. A cast of the interior.

Fig. 1 *b*. The same specimen seen on the side of the hinge.

Fig. 1 *c*. Portion of the surface of another specimen.

ARTEMIS CORDATA, n. s. PL. XXI. fig. 3 *a* & 3 *b*.

Shell broadly ovate, very gibbose, with a depression on the anterior margin near the beak: beaks large and incurved: shell covered with small irregular concentric wrinkles.

Length 1 inch; breadth $\frac{7}{8}$, thickness $\frac{3}{4}$ of an inch.

In limestone of the subcretaceous series between Torres Vedras and Sobral.

The deep depression on the upper part of the anterior margin gives this shell a cordate form when seen from the front.

PLATE XXI. fig. 3 *a*. Left valve.

Fig. 3 *b*. Side view of the same specimen.

ARTEMIS ELEGANTULA, n. s. PL. XIV. fig. 2 *a* & 2 *b*.

Shell nearly circular, with prominent beaks; gibbose; covered with regular concentric wrinkles between which are finer concentric lines.

Length and breadth $\frac{7}{8}$ths of an inch.

Abundant in the lowest beds of the hippurite limestone at Papel, on the road from Lisbon to Cintra.

A very elegant shell in form and marking; the hinge has not been seen, and the genus must be left in some doubt.

PLATE XIV. fig. 2 *a*. Exterior.

Fig. 2 *b*. Cast of another specimen.

ARTEMIS INELEGANS, n. s. PL. XX. fig. 3 *a* & 3 *b*.

Shell broadly ovate, approaching a triangular outline, slightly gibbose: beaks small and approximate: surface covered with irregular concentric lines and wrinkles.

Length $1\frac{1}{4}$ inch; breadth 1 inch; thickness $\frac{5}{8}$ths of an inch.

In limestone of the subcretaceous series in the cliffs at the Praia de Maçams, north of the Cintra hills.

PLATE XX. fig. 3 *a*. Exterior.

Fig. 3 *b*. Cast.

ASTARTE? DISCUS, n. s. PL. XXI. fig. 4 *a*, 4 *b*, & 5.

Shell transverse, broadly obovate, irregular, nearly flat. Dorsal margin straight: umbos very small and placed near the anterior extremity: anterior margin slightly excavated by a small, deep lunette: ventral and posterior margins rounded: ligament concealed in a deep hollow bounded by projecting sharp edges. Surface rough and uneven with irregular concentric wrinkles, and originally ornamented with dark irregular radiating lines.

Posterior muscle placed away from the margin on a broad flat elevation; anterior muscle close to the margin and near the umbo; third muscle well-developed.

Length $2\frac{3}{4}$ inches; breadth $3\frac{1}{4}$; thickness $\frac{1}{2}$ an inch.

From subcretaceous limestones between Sobral and Torres Vedras.

I have not seen the hinge of this singular shell, and expect that it will be found to constitute a new genus. The rough irregularity and great flatness of the exterior, and the sharp edges which project above

the ligament, together with the peculiar positions of the muscles, distinguish it from *Astarte*; but I leave it in that genus till more is known of it.

Plate XXI. fig. 4 *a*. Exterior.

Fig. 4 *b*. Dorsal view of the same specimen.

Fig. 5. Cast of the interior of another specimen.

Avicula Olisiponensis, n. s. Pl. XVIII. fig. 3.

Subrhomboidal, elongated, slightly oblique, nearly equivalve, gibbose: the anterior side very steep, anterior wing small: posterior side gradually sloping, with the posterior wing ill-defined: shell marked anteriorly with distant subsquamose lines of growth, on the posterior wing with waving folds, and on the middle portion with several elevated rays, which rise near the ventral margin into sharp ribs.

Length 2 inches; breadth 1½; thickness 1 inch.

In the upper beds of the hippurite limestone near Lisbon; rare.

Only one cast of this species has been seen with portions of the shell adhering to it; fragments of three sharp ribs remain near the ventral margin, and it is possible that one or two more similar ribs may be lost: these sharp, smooth ribs and the form of the shell are sufficient to distinguish the species.

Caprinula, D'Orbigny.

I hoped to have received, before publishing this paper, that part of M. d'Orbigny's 'Paléontologie Française' in which the *Caprinidæ* are described, but unfortunately I have only seen the plates of these shells without the text, and the notices which that author has previously published on the subject; I am therefore forced to draw up a description of this curious genus, which is necessarily less complete than it would have been if I had had the advantage of seeing his views of it fully explained.

The *Caprinulæ* are bivalve shells of great irregularity of form, with the valves very unequal; the lower valve which was probably attached when young is either curved or involute, the spire rarely exceeding two whorls: the two valves seldom lie on the same plane. The exterior is either smooth, wrinkled with concentric lines of growth or longitudinally fluted, and the markings of the two valves frequently differ in character, as is the case in several species of *Diceras*. The interior of both valves is divided into two larger and several smaller cavities by longitudinal plates which do not rise so high as the edge of the valves, and which divided the body of the mollusk into several lobes. In the upper valve of the species which I have seen, these plates are very oblique and were formed anew from time to time, cutting off the extremity of the cavity, which was abandoned.

The walls of the shells of both valves are perforated throughout by numerous longitudinal tubes, of unequal length and diameter, and open at the edges of the valves; these must have received thin, elongated lobes of the mantle. It is this peculiarity which appears to have led M. d'Orbigny to class the *Caprinidæ* in the family of *Ru-*

dista, in which arrangement I cannot follow him, as this one character appears outweighed by all the other analogies which connect the *Caprinidæ* with the *Chamaceæ*. To show the lobes of the shell and the longitudinal tubes as far as possible, sections are added to the figures of the species, and the fig. 2. Plate XVI. shows a fore-shortened view of the upper valve of *Caprinula Boissyi* nearly perfect.

The outer layer of shell is very thin, and is rarely preserved in the specimens from Lisbon: it seems to be of a different structure from the inner shell, as is the case in *Diceras*; but the bad condition of the specimens prevents my speaking with certainty on this head.

The hinge has not been seen, but it may be inferred from the strong plate or column *a* of the figure just quoted, which runs down the whole valve, that, as in *Chama* and *Caprina*, the principal feature of the hinge was a very strong tooth. The ligament appears to have been external and to have lain in the longitudinal furrow *b* of the same figure, in which it resembles that of the *Chamaceæ*: this ligamental furrow is well shown in the plates 536. figs. 2 and 3, 538. fig. 1, and 540. fig. 1, of the 'Paléontologie Française.'

All the species of *Caprinidæ* here described were found together in the hippurite limestone of Lisbon, contemporary with our chalk, and they all fall under M. d'Orbigny's definition of *Caprinula* (Comptes Rendus, 16 Aug. 1847). The genus *Caprina* appears distinct from *Caprinula*, but there hardly seem characters sufficient to distinguish *Caprinella* from the last-named genus; and the whole family appears to belong, together with *Diceras*, to the *Chamaceæ*.

CAPRINULA BOISSYI, D'Orb. T. Cret. 540. (*Post*, PL. XVI. fig. 1, 2, & 3.)

Shell very inequivalve, the lower valve spiral and ending in a blunt apex, with one or two whorls, marked by rough lines of growth; otherwise smooth: upper valve straight, covered with strong longitudinal flutings which are irregularly broken by the concentric lines of growth. A deep external channel marks the place where the ligament has interrupted the growth of the shell.

Very abundant in the hippurite limestone at Lisbon.

In very large specimens the spire is 9 inches across and the straight valve 9 inches long.—N.B. My specimens all show a blunter apex than M. d'Orbigny's figure.

PLATE XVI. fig. 1. A specimen with both valves nearly perfect, except that the lower valve has lost its surface.

Fig. 2. A siliceous specimen of the upper valve cleaned by acid: the edge is partially broken away, but the plates which divide the body of the animal into lobes, and the tubes which penetrate the walls of the shell are well seen. The thick plate *a* would probably end in a strong tooth similar to that in *Chama*. The external furrow *b* has held an external ligament, as in *Chama*, *Isocardia*, &c. The specimen is 6 inches long.

Fig. 3. A section of the valve, showing the tubes in the wall of the shell and the lobes of the body of the mollusk.

CAPRINULA BREVIS, n. s. PL. XVII. fig. 1 & 2.

Shell somewhat inequivalve: both valves slightly curved, short, and increasing very rapidly in diameter, so that the breadth at the juncture of the valves is about equal to the length of the longer valve. The junction of the valves is very slightly oblique.

Surface of one valve smooth, of the other covered with very fine longitudinal flutings?

In the hippurite limestone at Lisbon.

The largest specimen seen is $4\frac{1}{2}$ inches in diameter.

The species is not common at Lisbon, and I have only one fragment retaining the outer surface of the shell, which may perhaps belong to another species. *C. brevis* is readily distinguished from either of the other species by its peculiar proportions.

PLATE XVII. fig. 1. A young specimen nearly perfect.

Fig. 2. Section of an old specimen.

CAPRINULA D'ORBIGNII, n. s. PL. XVIII. fig. 1 & 2.

Subcylindrical: both valves slightly curved, and set rather obliquely together, so as to give the whole shell an irregular sigmoidal flexure. The valves are of very unequal length, but the end of the interior of the longer valve is cut off by septa, so that the cast of that valve is of about the same length as that of the other.

The exterior of both valves is similarly ornamented with strong uneven flutings which are frequently interrupted by strongly marked lines of growth.

Common in the hippurite limestone at Lisbon.

The usual size of this species is about 2 inches in diameter; but one fragment which I believe to belong to the species is above 4 inches in diameter. I have no perfect specimen, but many fragments are between 4 and 6 inches long.

I could not resist the temptation to name this species after M. Alcide d'Orbigny, to whom this family of shells is especially indebted.

PLATE XVIII. fig. 1. Portion of the exterior of both valves.

Fig. 2. Cast.

CAPRINULA DOUBLIERI, D'Orb. sp. (*Post*, PL. XVII. fig. 3 & 4.)

Caprinella Doublieri, D'Orb. Pal. Franç. T. Cret. pl. 541.

Lower valve of two whorls, the inner one increasing rapidly in size, the outer whorl of nearly the same diameter throughout. Upper valve very short and nearly smooth.

In the hippurite limestone near Lisbon.

I have seen few specimens of this species,—none with the valves united; I therefore take the proportions of the two valves from M. D'Orbigny's figure. My largest specimen is 4 inches across.

The section shows the same lobes of the body and tubes of various sizes down the walls of the shell as in the preceding species, for which reason I place it in *Caprinula* instead of *Caprinella*, of which the definition is to have all these tubes of the same size.

PLATE XVII. fig. 3 *a*. Lower valve with the surface destroyed.

Fig. 3 *b*. Section of the same specimen.
Fig. 4. Upper valve of another specimen.

CARDIUM CORRUGATUM, n. s. PL. XIV. fig. 3.

Nearly orbicular; covered with coarse irregular concentric wrinkles, except down the posterior edge, which has a few longitudinal irregular ribs.

Length 3 inches; breadth $2\frac{1}{2}$ inches; thickness 2 inches.

Found in the lowest beds of the hippurite limestone between Loures and Bucellas, and in subcretaceous limestone at Fontanellas, a little north of Cintra.

Distinguished from *C. Hillanum* and all the species of that group by its coarse, irregularly wrinkled surface: the longitudinal ribs are confined to a very small portion of the shell, in which it resembles *C. dissimile*, Sow. and *C. impressum*, D'Orb.

CARDIUM OLISIPONENSE, n. s. PL. XIV. fig. 4 *a* & 4 *b*.

Shell oval, very gibbose, inequilateral; covered with very numerous regular, fine, equal ribs radiating from the beak to the margin, which are separated by rounded interstices twice as wide as the ribs. Probably furnished also at each side with a few longitudinal rows of spines? Beaks produced and distant.

Length $2\frac{1}{4}$ inches; breadth $1\frac{3}{4}$ inch; thickness $1\frac{3}{4}$ inch.

Very abundant in the upper beds of the hippurite limestone at Lisbon.

The specimens of this shell found at Lisbon are all casts on which the ribbing is strongly marked; they show some traces of the bases of lateral spines. In form and marking it resembles the *C. Moutonianum*, D'Orb., *Cardita tuberculata*, Sow., from which it is distinguished by the regular equality of its ribbing, and by the ribs showing themselves on the interior of the valves.

PLATE XIV. fig. 4 *a* & *b*. Views of different specimens.

CORBULA COSTÆ, n. s. PL. XX. fig. 2.

Transversely subovate; slightly inequivalve, the left valve larger; beaks involute, placed near the anterior end; cardinal margin oblique; surface smooth, with regular, distant, slightly raised, concentric lines.

Length $1\frac{1}{8}$ inch; breadth $1\frac{1}{2}$ inch.

In subcretaceous limestone on the coast at San Pedro de Muriel, near Meirinha Grande.

This shell resembles *C. trigona*, Rœmer, but is more inequilateral and oblique. It is dedicated to Dr. F. A. Pereira da Costa, Professor of Mineralogy and Natural History of the Polytechnic School at Lisbon, to whose kindness I owe the specimen figured.

CORBULA EDWARDI, n. s. PL. XXI. fig. 2 *a*. & 2 *b*.

Transversely oblong, very inequivalve; truncated anteriorly, much produced posteriorly. Beaks very unequal, near the anterior end. Hinge-line straight, extending to the posterior extremity.

Left valve tumid; the beak folding over; covered with regular, elevated, concentric ridges. Right valve slightly tumid anteriorly, and depressed near the posterior end; covered with concentric, elevated ridges which are less regular and less elevated than those on the left valve; sharply truncated at the anterior edge.

Length $1\frac{1}{4}$ inch; breadth $1\frac{5}{8}$ inch; thickness $\frac{3}{4}$ inch.

From subcretaceous limestones between Sobral and Torres Vedras.

I have named this species after Señor Edwardo Augusto Boaventura, to whom I am indebted for all the specimens from this locality.

Plate XXI. fig. 2 *a*. Right valve.

Fig. 2 *b*. Left valve.

Cyprina globosa, n. s. Pl. XV. fig. 1 *a* & 1 *b*.

Subglobose; nearly smooth, with some irregular concentric wrinkles: posterior side rounded, with two slight longitudinal depressions: umbones rounded and very thick; lunette broad and ill-defined.

Shell very thick. Anterior muscular impression very deep.

Length $1\frac{3}{4}$ inches; breadth 2 inches; thickness 2 inches.

Found in the upper beds of the hippurite limestone at Lisbon.

The specimen has lost the shell of one valve, and thus represents the exterior of one valve and the cast of the interior of the other. It is remarkable for the roundness and thickness of the valves near the hinge and for the great solidity of the shell.

Plate XV. fig. 1 *a* & *b*. Two views of the same specimen.

Cyprina cordata, n. s. Pl. XV. fig. 2 *a* & 2 *b*.

Ovate, thick, concentrically wrinkled? Posterior side rounded. Beaks incurved. Lunette large. Anterior extremity prominent.

Shell thick, anterior muscular impression deep.

Length $2\frac{1}{4}$ inches; breadth $2\frac{1}{4}$ inches; thickness $1\frac{1}{2}$ inch.

From the upper beds of the hippurite limestone at Lisbon.

The shell of this species seems to have been very liable to decay, as while internal casts are very abundant, only one weathered specimen has been found with the shell.

Plate XV. fig. 2 *a* & *b*. Two views of the same specimen, of which the surface is much decayed.

Cyprina securiformis, n. s. Pl. XXII. fig. 1–3.

Cordato-triangular, with the dorsal margin continued in a regular curve from the umbo to the posterior angle; ventral margin rounded; anterior margin with a deep depression below the beaks, which are placed very forward. The dorsal side is nearly perpendicular to the rest of the valve and marked with two slight longitudinal carinæ. Surface nearly smooth, with some concentric wrinkles which are stronger near the ventral margin.

Length 2 inches; breadth $2\frac{1}{2}$ inches; thickness 1 inch.

Plate XXII. fig. 1. Left valve.

Fig. 2. Dorsal view of another specimen.

Fig. 3. Hinge of a third specimen.

From subcretaceous limestone between Sobral and Torres Vedras, and also about three miles south-west of Alenquer.

This shell has some resemblance in form to *Astarte subtrigona*, Goldf., and to *Cytherea trigonellaris*, Voltz, from both of which it is readily distinguished by the steepness of the dorsal side and more triangular outline. The muscular impressions are small.

DIANCHORA? BICORNIS, n. s. PL. XXVI. fig. 4 & 5.

Shell irregularly gibbose; variable in form; attached; beaks of both valves considerably produced; shell very thin and fragile; both valves covered with fine, close-set, nearly equal, rounded ribs, which are crossed at irregular intervals by distinct concentric lines of growth. Hinge?

Length $1\frac{1}{2}$ inch.

In beds of limestone of the oolitic series, above the coal, at Cape Mondego.

This curious shell is evidently related to the *Dianchoræ*, Sow., which have been placed by Deshayes, Goldfuss and D'Orbigny in the genus *Spondylus* upon insufficient evidence, as their hinges have not yet been seen. They differ from the true *Spondyli* in their thin fragile shells, the interior of which shows all the markings of the exterior; these contrast most remarkably with the thick solid shells of *Spondylus*, which are lined internally with constantly accumulating deposits of shelly layers. Deshayes has suggested as a solution of this difficulty, that the inner thick layers of these species decayed readily, leaving only the outer thin layer preserved. This is a mere assumption unsupported by any evidence, and is in the highest degree improbable, as they are found in various strata and in different countries in the same state of preservation, and uniformly with only a thin shell.

The hinges of my specimens are broken, as is usually the case in this and other species: this seems to mark some peculiarity which has not yet been explained. Perhaps the animal fixed itself to one body by a byssus passing through the hinge-area, while the shell was cemented by calcareous matter to any other body which touched it, and the shell may have broken off, leaving the hinge attached by the byssus. The *Spondyli* also appear to have been attached by a byssus through the hinge-area when young, but to have dropped this connection as they grew older and closed up the aperture through which the byssus passed, the trace of which remains in the suture down the middle of the hinge-area of the lower valve.

The different specimens of *D. bicornis* vary much both in size and form; the latter seems to have depended in a great degree on the size and position of the body to which they attached themselves.

PLATE XXVI. fig. 4. An old specimen.

Fig. 5. Side view of a young shell.

DICERAS FAVRI, n. s. PL. XV. fig. 3*a*, 3*b*, & 3*c*, and PL. XX. fig. 9.

Shell irregular, with very dissimilar valves; the larger valve attached when young, spirally twisted, divided longitudinally in nearly

equal parts by a sharp, elevated keel; the anterior side wrinkled with coarse irregular folds, which are crossed near the lip in old shells by longitudinal wrinkles; posterior side nearly smooth with irregular lines of growth. Smaller valve incurved and entirely smooth.

Length 2 to 3 inches.

Abundant in the upper beds of the hippurite limestone at Lisbon, and in the subcretaceous limestone of the cliff of the Praia de Maçams near Cintra.

This curious shell is readily distinguished by the sharp ridge along the larger valve. It resembles the *D. Lucii* (as seen in M. Favre's figures, 'Observations sur les Diceras,' pl. 1. fig. 2. &c.), both in the wrinkling of the anterior side of the larger valve and in the contrast which that presents to the smoothness of the smaller valve. My specimens do not show the hinge completely; the casts of both valves bear the deep impression of a strong plate proceeding from the umbo nearly to the edge of the valve (see fig. 3 *c*), as is shown in the figure of *D. Lonsdalii* (Geol. Trans. 2nd series, vol. iv. pl. 13. fig. 4), and in M. Favre's fig. 5, 6 & 7 of plate 5, where it is marked *m*. This plate appears to bound the muscle, as in *Cucullæa*, &c., and is no way connected with the hinge, as might be inferred from M. Favre's description (p. 15, and pl. 5. fig. 1), where I presume that the artist has misrepresented the plate *m* in question.

The Portuguese specimens show the different layers of shell described by M. Favre, after whom I have much pleasure in naming the above species, in gratitude for his valuable additions to our knowledge of this curious genus.

Plate XV. fig. 3 *a* & *b*. Two views of the same specimen, from the hippurite limestone.

Fig. 3 *c*. Cast of the interior of another specimen, from ditto.

Plate XX. fig. 9. Small specimen from the subcretaceous beds of the Praia de Maçams.

Exogyra plicata, Lamarck, sp.

E. plicata, Goldfuss, pl. 87. f. 5.
E. flabellata, Goldfuss, pl. 87. f. 6.
Ostræa Boussingaultii, D'Orb. T. Crét. pl. 468.
O. flabellata, D'Orb. T. Crét. pl. 475.
O. Matheroniana, D'Orb. T. Crét. p. 485.
Gryphæa harpa, Forbes, Journ. of Geol. Soc. vol. i. pl. 3. f. 12.

Few species have been more subdivided than the *Gryphæa plicata* of Lamarck, partly owing to the variations of its form and partly to the determination of the author who has laboured most efficiently in this field to find a distinct species in each subdivision of the cretaceous system, until by a strange fatality the original specific name seems in danger of dropping through entirely.

The specimens which I have brought from Portugal are principally derived from two localities, belonging to two very distinct parts of the cretaceous system: the hippurite limestone or upper bed representing the chalk, well exposed at the quarries in the valley of Alcantara close

to Lisbon, furnishes in abundance the following varieties of M. D'Orbigny, *O. Boussingaultii, O. flabellata, O. Matheroniana,* of which the first is the most abundant form.

The limestone beds of the coast north of Cintra at the Praia de Maçams, which lie low in the subcretaceous series, are crowded with the same three varieties, *O. Boussingaultii,* D'Orb., *O. flabellata,* D'Orb., *O. Matheroniana,* D'Orb., so that in Portugal the different varieties of this species are found together in the same bed both in the upper and the lower part of the cretaceous series.

The serrations which run partially round the interior of the valves at a slight distance from their edge (D'Orb. pl. 468. f. 5, pl. 485. f. 7; Goldf. pl. 87. f. 5 *c*), depend on the age of the shell, and must not be taken for specific characters: they are seldom seen on very young shells, and become obliterated and covered up in very old ones. The tooth which M. D'Orbigny assigns as one of the characters of the *O. Matheroniana,* p. 738, and pl. 485. f. 7, is also an uncertain character, varying in development in individuals from the same locality and often obliterated in old shells.

As the principal differences between the three forms, *O. Boussingaultii, flabellata* and *Matheroniana,* appear to consist, according to M. D'Orbigny, in their having been found in France in different beds, it may be hoped that now they have been found together in Portugal, they may be admitted to be one species.

In the subcretaceous beds north of Cintra this species is found from 1 to near 5 inches in length; the plications are faint in those parts of the shell which are of later growth, and towards the edges the old shells are nearly smooth; at this stage of growth the shell somewhat approaches the form of the *E. sinuata.*

Exogyra Olisiponensis, n. s. Pl. XIX. fig. 1 & 2.

Shell nearly hemispherical: upper valve thick, slightly gibbose, covered with regularly concentric scales, the beak incurved in the plane of the valve: lower valve very thick and very gibbose, regularly rounded on the anterior margin and somewhat produced posteriorly: the surface squamose, with the edges of the scales raised up into short ribs, of which there are ten or twelve near the margin of an old shell; in some specimens the ribs are nearly continuous, in others they only occur near the margin of the scales, while in others they are hardly visible; the surface of the valve between the ribs is nearly smooth: beak of the lower valve laterally involute; the surface of attachment usually small.

In the upper beds of the hippurite limestone at Lisbon.

Length 4 inches; breadth 3 inches; thickness $2\frac{1}{2}$ inches.

In the young state, when about $1\frac{1}{2}$ inch long, this shell resembles *E. laciniata,* Nilsson, but the great size which it reaches and the greater convexity of its lower valve have prevented me from uniting them.

Plate XIX. fig. 1. Lower valve, strongly ribbed.

Fig. 2. Upper valve of a smaller specimen.

Gervilia Fittoni, n. s. Pl. XXIII. fig. 3–6.

Shell elongated, subrhomboidal, very oblique, nearly equivalve; posteriorly produced and flattened; anterior wing short, tumid and indistinct. Very slight sinus for the passage of a byssus, which is most marked on the left valve. Dorsal margin straight; hinge-area very deep, and enlarging anteriorly even in front of the umbo: ligamental sockets very unequal and usually few. Irregular dental callosities on the hinge-area; those before the umbo nearly perpendicular, those behind it sloping.

Length $1\frac{1}{2}$ inch; breadth $3\frac{1}{2}$ inches; height $\frac{3}{4}$ of an inch.

Abundant in subcretaceous limestone between Torres Vedras and Sobral.

Very closely resembling *G. Sobralensis*, this species is distinguished by the perpendicular position of the anterior teeth, and by the greater height of the hinge-area, which continues to increase in height quite to the anterior extremity; whereas in most species of the genus its height is greatest at the umbo. The ligamental sockets in old shells are usually three; but one specimen, fig. 5, has them more numerous, though in other respects agreeing with this species.

Fig. 3. Exterior.

Fig. 4. Interior of another specimen.

Fig. 5. Interior of a variety with the ligamental sockets numerous.

Fig. 6. Hinge-area of a young shell.

I have named this species after Dr. Fitton, to whom all geologists are indebted for his labours on the subcretaceous strata, and to whose friendship I owe more than I can here venture to express.

Gervilia Sobralensis, n. s. Pl. XXIII. fig. 1 & 2.

Shell elongated, very oblique, subtriangular, tumid, nearly equivalve; produced posteriorly into a blunt point; anterior wing tumid, and faintly separated by a slight diagonal depression, which is most marked on the right valve.

Hinge-area equal to about half the breadth of the shell; with two ligamental sockets in young, and four in old shells, of very unequal size. Hinge-teeth numerous, very unequal, and radiating from the umbo; those in front of the umbo sloping forward at angles from 40° to 60°, those behind the umbo sloping backward from 10° to 30° with the hinge-line. As the animal grows old, shelly matter is deposited over those parts of the hinge-area which are not protected by the ligament, and the teeth are nearly concealed except in the ligamental sockets, where their traces are seen under the ligament, and along the inner margin of the hinge-area.

Sinus for the escape of the byssus very slight.

Length $1\frac{1}{4}$ inch; breadth 3 inches; thickness $1\frac{1}{4}$ inch.

Abundant in subcretaceous limestone between Sobral and Torres Vedras.

The characters by which this species is most readily distinguished are the short tumid anterior wing, almost continuous with the rest of

the valve, and the anterior teeth sloping forwards, which remain visible at all ages of the animal.

Plate XXIII. fig. 1. Fragment of an old shell, showing the hinge.

Fig. 2. Hinge of a young shell.

Mytilus Beirensis, n. s. Pl. XXVI. fig. 1.

Shell triangular, subfalciform, with a rounded keel curving from the beak to the posterior extremity; covered with numerous concentric wrinkles: posterior portion rounded, with a few faintly marked, large folds radiating from the beak: anterior side steep, and slightly excavated: beaks pointed and terminal.

Length 3 inches; breadth $1\frac{1}{4}$ inch; thickness 1 inch.

From limestone of the oolitic series above the coal-beds at Cape Mondego.

This species is readily distinguished by the waving folds on its posterior slope. The shell is nearly straight when young, and grows falcate gradually.

Mytilus Morrisii, n. s. Pl. XXII. fig. 5 *a* & 5 *b*.

Shell falciform, with an elevated keel dividing the valves into two very unequal portions, the posterior gibbose and rounded, the anterior excavated, and nearly perpendicular to the plane which separates the valves; with the exception of a small smooth space near the beak on the anterior side, the valves are covered with numerous rounded bifurcating ribs, crossed by concentric lines, which latter are most strongly marked on the anterior side; the ribs on the posterior side are coarse, and radiate from the beak; those on the anterior side rise from the keel, and are much finer than the others: beaks pointed and terminal.

Length $3\frac{1}{2}$ inches; breadth $1\frac{1}{2}$ inch; thickness $1\frac{1}{2}$ inch.

Abundant in limestone of the subcretaceous series between Sobral and Torres Vedras.

I have met with no described species with which to compare this handsome Mytilus. It is named after my friend Mr. John Morris, as a slight acknowledgement of the great assistance which I have received from him in examining the shells described in this memoir.

Plate XXII. fig. 5 *a*. Side view.

Fig. 5 *b*. Front view.

Ostræa prælonga, n. s. Pl. XX. fig. 4.

Flat, elongated, with nearly parallel, flexuous margins; attached by nearly the whole lower valve; hinge-area very long and pointed; upper valve nearly smooth, with concentric squamose lines of growth.

Length 4 or 5 inches; breadth 1 or $1\frac{1}{2}$ inch.

In limestone of the subcretaceous series in the cliffs at the Praia de Maçams, north of the Cintra hills.

This oyster is related to the *O. acutirostris* of Nilsson, but it exceeds that shell in the length of its narrow hinge-area, which is sometimes $1\frac{1}{2}$ inch long, and projects an inch beyond the upper valve.

OSTRÆA PUSTOLOSA, n. s. PL. XXIV. fig. 4 *a* & 4 *b*.

Very thick, irregular, ovate, transverse or rhomboidal, deep; hinge-area very large. Lower valve gibbose, slightly attached, the rest of the valve irregularly covered with warty swellings: upper valve flat, nearly smooth or slightly pustulose.

Length $2\frac{1}{2}$ to 3 inches; breadth about 2 inches.

Very abundant in limestones of the subcretaceous period between Torres Vedras and Sobral.

This oyster appears to have increased its depth and thickness, while adding very little to its circumference. It is frequently broader than long; and the large hinge-area often covers more than a third of the area of the shell. These characters and the warty or pustulose appearance of the surface distinguish it readily.

PLATE XXIV. fig. 4 *a*. Lower valve.

Fig. 4 *b*. Hinge of lower valve.

PECTEN (JANIRA) INCONSTANS, n. s. PL. XIX. fig. 3 *a* & 3 *b*.

Shell heptagonal, nearly circular; convex below, slightly concave above. The lower valve nearly hemispherical, with an incurved umbo, ornamented with about twenty elevated, rounded, nearly equal ribs, separated by unequal rounded hollows, in some of which there are one or two fine ribs. Every fourth rib is longer than the rest, and is produced into the angles of the shell; some of these longer ribs are also more elevated than the rest.

Upper valve slightly convex, covered with seventy to eighty ribs of varying form and size, separated by very unequal hollows. The principal ribs which run to the three front angles of the shell are divided into four by one broad central furrow, and two slight lateral furrows down each, and they are very unequally elevated, one being always much more prominent than its fellows: towards the lateral angles the ribs are much subdivided and very unequal.

Both valves are covered by well-marked concentric lines.

Ears small, placed very forward on the upper side of the shell.

Diameter 3 to 4 inches.

In the upper beds of the hippurite limestone at Lisbon; not common.

This is closely related to *Pecten quadricostatus*, and, as in that shell, every fourth rib on the lower valve is of more importance than its fellows; but on the upper valve the ribs are more angular, and more numerously and irregularly divided than in that species. The most singular feature in the shell is the irregular elevation of the principal ribs, one of the two middle ones being always depressed and the other elevated, which gives a very awkward appearance to the shell: all the specimens seen agree in this respect. The ears are broken in all my specimens.

If all M. D'Orbigny's species of *Janira* are considered distinct, this must also rank as a distinct species; but if farther observation leads us to throw many of those together, then this shell will probably be regarded as only a variety of *P. quadricostatus*.

Plate XIX. fig. 3 *a*. Upper valve.
Fig. 3 *b*. Side view of the same specimen.

Pecten Lusitanicus, n. s. Pl. XXIV. fig. 3.

Shell oval, with the posterior and ventral margins rounded, and the anterior margin angular; valves unequally convex, ornamented with strongly marked concentric lines of growth, crossed by finely impressed radiating lines, which become almost obsolete towards the margin. Anterior ear covered with decussating lines: posterior ear?

Length $1\frac{3}{4}$ inch; breadth $1\frac{1}{2}$ inch.

In limestone of the subcretaceous series between Torres Vedras and Sobral.

This Pecten has some resemblance to the *P. obscurus*, Sow., *P. lens*, Sow., and *P. annulatus*, Sow., which are oolitic species: it is distinguished from them all by greater want of regularity, and by the angular outline of the anterior margin.

Perna? fragilis, n. s. Pl. XVIII. fig. 4.

Subquadrate, anterior side a little excavated immediately below the beaks; gibbose anteriorly and gradually sloping posteriorly; shell very thin, with numerous, concentric, subsquamose lines of growth: hinge?

Length $1\frac{3}{4}$ inch; breadth $1\frac{3}{4}$ inch; thickness $\frac{1}{8}$ of an inch.

In the upper beds of the hippurite limestone near Lisbon; rare.

I have only one imperfect cast of this species, with portions of the shell adhering to it. It differs from most of the species of *Perna* in the extreme thinness of its shell, which might lead us to class it with *Inoceramus*; but the depression of the anterior part of the right valve near the beak for the passage of a byssus unites it to *Perna*. In general appearance this species has considerable resemblance to *Perna polita*.

Plate XVIII. fig. 4. Right valve.

Perna Lusitanica, n. s. Pl. XXIII. fig. 7 & 8.

Subrhomboidal, very thick and heavy, marked irregularly by the lines of growth: anterior side deeply depressed, and sloping inwards; posterior side slightly rounded away towards the palleal margin: cardinal margin arched. Hinge-areas very broad, receding one from another, and projecting anteriorly: ligamental hollows long and numerous, broader than the intervening spaces, and slightly increasing in width posteriorly, about twenty-four in number in a large specimen. Valves very thick, especially towards the hinge; space occupied by the animal nearly rectangular and very small in proportion to the whole shell. Right valve larger and thicker, and with a deeper hinge-area than the left.

Found in subcretaceous limestone, between Enxarra dos Cavalheiros and San Sebastian, and between Sobral and Torres Vedras.

Nearly allied to *P. Ricordeana*, D'Orb., from which it differs in its less regular and more rounded form and in the arched cardinal margin. These differences are less visible in young than in old

shells, and it is possible that farther comparison may show them to belong to the same species.

The external proportions vary materially in different specimens; in some the length but slightly exceeds the breadth, in others it is fully double the width.

The dimensions of an average specimen are, length 6 inches; breadth 4½ inches; thickness 3 inches.

Plate XXIII. fig. 7. Right valve of a young shell.

Fig. 8. Hinge of the right valve of another specimen.

Perna polita, n. s. Pl. XXIV. fig. 1 & 2.

Subrhomboidal; anterior side excavated; front regularly rounded; posteriorly produced into a depressed wing, which is separated from the rest of the valve by a sudden depression: surface covered with very regular scaly lines of growth, between which it is quite smooth. Ligamental hollows broad.

Length 1½ inch; breadth 1½ inch; thickness ¾ of an inch.

Found in subcretaceous limestones, three miles south-west of Alenquer.

This is a small neat shell, which wants the usual irregular roughness of the Pernæ, instead of which it has the general aspect of an Avicula or a Gervilia. In outline and marking it much resembles *Gervilia enigma*, D'Orb., except that it entirely wants the anterior wing of that species.

Tellina Sobralensis, n. s. Pl. XXI. fig. 1 *a* & 1 *b*.

Shell ovato-triangular, gibbose, irregularly striated and wrinkled by concentric lines of growth. Right valve gibbose, with an obscure rounded fold between two broad, shallow depressions: left valve with a broad, shallow depression down the middle, and a rounded, elevated fold near the anterior extremity.

Length 2½ inches; breadth 3¼ inches; thickness 1¾ inch.

From subcretaceous beds between Sobral and Torres Vedras.

Neither the hinge nor the interior of this shell have been seen.

Plate XXI. fig. 1 *a* & *b*. Two views of the same specimen.

Trigonia Lusitanica, n. s. Pl. XXII. fig. 4 *a* & 4 *b*.

Lyrodon literatum?, Goldf. pl. 136. f. 5 *c*, & 5 *d*, excluding f. 5 *a*, *b*, *e*, *f* & *g*.

Ovato-subtriangular; anterior side short and nearly straight; posteriorly elongated; front regularly curved: ornamented with curved rows of tubercles which bifurcate towards the anterior angle of the shell, and which are continued over the anterior side in irregular, faint, sharp ridges. Tubercles of two sizes, which might be separated by a diagonal line drawn from the umbo to near the middle of the front of the shell. Posterior side of the valve sloping, divided into two uneven parts by a deep furrow: the hinder area crossed by rows of small tubercles, the front area coarsely striated. Surface of the shell

covered by irregular concentric lines of growth, which are best seen between the tubercles.

Length 2 inches; breadth 3 inches; thickness $1\frac{1}{2}$ inch.

Abundant in limestone of the subcretaceous period between Torres Vedras and Sobral.

Goldfuss has figured a specimen of this shell from Torres Vedras, uniting it to *T. literata* of the lias and inferior oolite, from which it is quite distinct. The Portuguese species is a neater and more regular shell, and may be distinguished from *T. literata* by its straight front and by the regular rows of small tubercles which cover nearly half its surface, while the same part is covered in *T. literata* by broad coarse ribs. The principal character which is common to the two species is the bifurcation of the rows of tubercles towards the front of the shell; this is not common among the Trigoniæ, but is seen also in *T. muricata*, *T. dædalea*, *T. nodosa* and *T. duplicata*.

The *Trigonia muricata*, Goldf. sp., which is found in the same locality, is so closely allied to *T. Lusitanica*, that it may be doubted whether they should not be united: the general form of the two shells is the same, but *T. muricata* has about twice the number of rows of tubercles, which are smaller and more numerous in each row than in *T. Lusitanica*.

Plate XXII. fig. 4 *a* & *b*. Two views of the same specimen.

Spirifer Beirensis, n. s. Pl. XXVI. fig. 2 *a* & 2 *b*.

Shell ovate, moderately convex, minutely punctated: dorsal valve regularly arched, with a produced incurved beak, and a broad shallow ill-defined sinus extending from the beak to the margin, where it occupies above a third of the width of the shell; ventral valve nearly circular, with a broad, rounded, ill-defined mesial fold: both valves are smooth near the hinge, and are ornamented towards the front margin with faint, rounded, longitudinal folds, separated by shallow rounded furrows; of these there are about eight on each wing, of which the lateral ones are very obscure; faint traces of obscure folds in the sinus: a few strong concentric rings on each valve. Hinge-area rounded off and undefined.

Length 1 inch; breadth $\frac{6}{5}$ of an inch; thickness $\frac{1}{2}$ inch.

In Jurassic limestone at Vendas Novas, four leagues north-west of Coimbra on the road to Aveiro.

This shell belongs to the same group of punctated Spirifers as *S. Walcottii*, *S. granulosus*, and *S. verrucosus*, all of which are found in the lias. It was found in company with *S. granulosus* and other shells peculiar to the lias. It is distinguished from all its congeners by its elongated ovate form and obscure ribbing, in which it closely resembles many of the recent *Terebratulæ*, especially *T. dentata*. In fact, of all the Spirifers known, this is perhaps the species most nearly allied to the Terebratulæ.

The ribbing is much more marked on the dorsal than the ventral valve; but as the only specimen seen appears somewhat worn, this may be partly accidental.

The interior has not been seen.

Plate XXVI. fig. 2 *a* & *b*. Two views of the same specimen.

Terebratula Beirensis, n. s. Pl. XXVI. fig. 3 *a* & 3 *b*.

Shell nearly quadrangular, with rounded sides; ornamented with about thirty-two obtuse and slightly elevated ribs, eight of which are raised up near the anterior margin in the mesial fold; dorsal valve flat posteriorly, with a deep sinus anteriorly; ventral valve very convex, and produced at the anterior margin in an elevated fold, which, as well as the corresponding sinus on the dorsal valve, only commences at the middle of the shell; sides depressed and smooth near the hinge, somewhat dilated anteriorly; beak incurved.

Length and breadth 1 inch; height $\frac{1}{2}$ inch.

From the jurassic limestone below the coal at Cape Mondego.

This shell is more nearly related to *T. vespertilio*, Brocchi, of the cretaceous system, than to any other described Terebratula: it differs from that species in having the front more produced than the sides, the beak much incurved, only about half as many ribs, and other minor points. Among the jurassic species it is nearest to *T. tetrahedra*, Sow., from which its dilated sides and obtuse flattened ribs separate it widely. Only one specimen has been seen.

Plate XXVI. fig. 3 *a* & *b*. Two views of the same specimen.

Natica Lusitanica, n. s. Pl. XXIV. fig. 5 *a*, 5 *b*, & 5 *c*.

Shell subglobose, with a slightly produced spire of three volutions; marked with faint lines of growth, otherwise nearly smooth. Mouth broadly lunate. Columella solid.

Length $\frac{1}{4}$ of an inch; diameter $\frac{1}{4}$ of an inch.

From limestone of the subcretaceous period, three miles south-west of Alenquer.

Plate XXIV. fig. 5 *a*. Natural size.

Fig. 5 *b* & 5 *c*. Magnified.

Nerita turbinata, n. s. Pl. XXIV. fig. 6 *a* & 6 *b*.

Semi-globose; spire small, partly immersed; whorls slightly flattened above, tumid in the middle, and a little produced at the base, crossed by numerous strongly marked lines of growth.

Length $\frac{1}{3}$ of an inch.

Found in limestone of the subcretaceous series, three miles south-west of Alenquer.

This elegant little shell somewhat resembles *N. costata*, Min. Con. 460. f. 5 & 6, but has not the strong costæ of that species: the produced columella, which has been partly broken in the only specimen found, gives it a somewhat turbinated form.

Plate XXIV. fig. 6 *a*. Natural size.

Fig. 6 *b*. Magnified.

Neritina bicornis, n. s. Pl. XXIV. fig. 7.

Semi-oval, slightly and regularly convex, with the margins produced into two nearly equal pointed ears; spire produced and slightly

oblique: colour tawny, with thin dark lines radiating from the apex to the margin, some of which bifurcate; these are crossed by well-marked lines of growth. Aperture semi-lunar; body-lip expanded into a gibbose callosity; outer lip sharp and extended to the two ears.

Length $\frac{5}{8}$ of an inch; breadth $\frac{1}{2}$ an inch.

Found in limestone of the subcretaceous series, two miles south-west of Alenquer.

This curious shell belongs to the division of the Nerites, of which *Neritina auriculata*, Lam., is the type; but it is more nearly equilateral than any recent species. There can be little doubt that it must have inhabited fresh water, but all the shells found near it belong to marine genera. The colours are most remarkably preserved. Only one specimen has been seen, of which the spire is not quite perfect.

PYRAMIDELLA? SAGITTATA, n. s. PL. XX. fig. 8.

Shell conical, short, smooth. Spire of four or five whorls, which enlarge rapidly, the last whorl forming about half the length of the shell. Mouth narrowed by two strong thick plaits on the columella, which are continued through the whole spire; the upper plait projects diagonally, the lower horizontally, until they nearly meet and divide the interior of the whorl into three lobes, giving the section a resemblance to the head of a broad arrow. Columella umbilicated.

Length $2\frac{1}{4}$ inches; breadth 1 inch.

Spiral angle 45°, regular. Sutural angle 55°. Basal angle 120°.

Found in limestone of the subcretaceous series, in the cliffs of the Praia de Adrarga, north of the Cintra hills.

Unfortunately all the specimens of this very curious shell are imperfect, and the specific characters rest principally on the enormous size of the fold of the columella, and the form of the interior of the whorl. In general it is hardly advisable to name such a fragment, but in this shell the internal characters are so very remarkable as to justify giving it a name, although we have seen little more than a section of the shell. I have placed it in *Pyramidella* with some hesitation, as it has little resemblance in general appearance to the other species of that genus: it differs from *Nerinæa* in the simple edge of the outer lip and the rapidity of increase of the whorls.

ROSTELLARIA COSTÆ, n. s. PL. XX. fig. 1.

Shell elongato-conical; spire regular, of eight or more volutions; whorls gibbose, smooth in the middle, but ornamented round their upper edge with short reflexed folds, and round their base with longer, faint, oblique folds sloping forwards; several concentric grooves round the base of the body-whorl.

Length $3\frac{1}{2}$ inches; diameter $1\frac{1}{2}$ inch.

Spiral angle 35°. Sutural angle about 90°.

Found in limestone of the subcretaceous series at San Pedro de Muriel, near Meirinha Grande, by Dr. F. A. Pereira Costa, to whom I am indebted for the specimen, and after whom it is named.

TEREBRA OBCONICA, n. s. PL. XX. fig. 5 *a* & 5 *b*.

Shell turreted; spire formed of numerous volutions arranged in regular steps; whorls smooth, angular above, flattened at the side and slightly wider above than below; a groove at the angle of the whorl left by the posterior canal: aperture lozenge-shaped.

Length about $1\frac{3}{4}$ inch; diameter $\frac{3}{8}$ of an inch.

Spiral angle 15°. Sutural angle 80° to 85°.

In subcretaceous limestone at Cape Espichel.

This is a remarkably shaped shell, the spire appearing as if formed of a set of reversed cones inserted one within another.

PLATE XX. fig. 5 *a*. Exterior.

Fig. 5 *b*. Section.

TURBO MUNDÆ, n. s. PL. XX. fig. 7 *a* & *b*.

Shell depressed, heliciform; spire very small, of three or four volutions: whorls tumid, increasing very rapidly, ornamented with transverse, tuberculated striæ, crossed by strongly marked lines of growth, the tubercles being at the intersection of the lines; the upper part of the whorl is also ornamented with reflexed, tuberculated plications.

Diameter $\frac{1}{3}$ of an inch.

From subcretaceous limestone at Figueira, at the mouth of the Mondego.

A very elegant little shell, which has some resemblance to *T. plicatilis*, Desh.

PLATE XX. fig. 7 *a*. Natural size.

Fig. 7 *b*. Magnified.

TURRITELLA CINTRANA, n. s. PL. XX. fig. 6 *a* & *b*.

Shell turreted; spire of six or eight gibbose whorls ornamented with smooth, projecting, transverse ribs, crossed by very faint lines of growth: ribs increasing in number from two on the upper to five on the lower whorls, the two middle ribs constantly larger than the others.

Length $1\frac{1}{4}$ inch; breadth $\frac{1}{2}$ an inch.

Spiral angle rounded, varying from 50° in the young to 25° in the old shell. Sutural angle 100°.

Abundant in shale of the subcretaceous series in the cliffs at the Praia de Maçams, north of the Cintra hills.

PLATE XX. fig. 6 *a* & 6 *b* are two specimens of different age.

TURRILITES BEIRENSIS, n. s. PL. XXVI. fig. 6.

Shell nearly flat? with a very low spire? composed of rounded whorls, of which about one-third is concealed by the outer whorl, ornamented with fasciculated ribs, and a slightly elevated line along the middle of the back; umbilicus large and smooth; about thirty strong, elevated ribs rise close to the umbilicus, each of which soon divides into three or four finer ribs which run nearly straight and of a uniform size to the slight keel on the middle of the back, where they do not meet the ribs from the other side of the whorl, but usually alternate with them; back very round; aperture broadly lunate.

Diameter $1\frac{1}{2}$ inch.

Found in jurassic limestone at Montemor-velho.

Only one fragment of this shell has been found, which is not sufficient to furnish a good specific description; yet it is of too much interest to be omitted, both from the rarity of *Turrilites* in beds of this age, and from this species presenting a character of ribbing not before seen in the genus: its flattened spire connects it with the Ammonitiform species of Turrilites, *T. Valdani*, *T. Coynarti* and *T. Boblayei*, described by M. D'Orbigny, all of which, like this shell, are of the age of the lias.

Description of Fossil Echinidæ *from* Portugal.

By Professor E. Forbes.

Echinus Olisiponensis, sp. nov. Pl. XXV. fig. 1.

E. assulis numerosis, angustissimis, dense tuberculatis; tuberculis primariis parvis, æqualibus, in seriebus horizontalibus undulatis dispositis; poris ambulacralibus omnibus in seriebus triplicibus obliquis dispositis.

This pretty species belongs to the group of *Echini* which Agassiz has separated as a genus under the name of *Polycyphus*, distinguishing the section from his (not Gray's) *Arbacia*, with which it has a common habit and the character of a general diffusion of numerous equal tubercles over the plates, by the pores being arranged in triple series instead of in a single line. But the latter character I have shown elsewhere (British Organic Remains, Dec. 1. pl. 6) to be fallacious, and a misinterpretation of the true structure, which in no essential respect differs from that presented by the genus *Echinus*; nor can *Polycyphus* be regarded in any other light than as a subdivision of the same genus of no great value.

The species before us is regularly melon-shaped, but without any rugosities or inequalities of its sides. The whole surface, divided into five broad and five narrow segments by two ambulacra, is studded with small, equal, but conspicuous tubercles; the interstices between them are covered with miliary granules. The interambulacral plates towards the centre (regarding their horizontal dimension as the length) are very long and narrow; those towards the middle bear about six tubercles, arranged in a somewhat undulated fashion, each row, ascending towards the ambulacra and again towards the interambulacral suture, depressed in its centre. The total number of tubercles arranged across the centre of an interambulacral area is consequently twelve. The ambulacral plates bear similar tubercles, two on each plate. Opposite each interambulacral plate, there are in each ambulacrum three pairs of pores, each series of three pairs arranged obliquely and with a slight undulation of direction, but not overlapping the commencement or termination of the next series. This arrangement is constant and similar from the mouth to the vertex. The mouth is circular, and distinctly notched near each ambulacrum. The anal and ocular plates have been destroyed in the specimen examined.

Dimensions.— Breadth $\frac{10}{12}$ inch; height $\frac{7}{12}$ inch; breadth of mouth $\frac{4}{12}$ inch; breadth of anal disk $\frac{3}{12}$ inch. Number of interambulacral plates in each vertical series about 22.

Found in the hippurite limestone near Lisbon.

Although this species closely resembles *Echinus granulosus*, its nearest ally is *Echinus nodulosus* (Goldfuss, tab. 40. fig. 16), a species found in the Calcaire à polypiers of Normandy, Luc, and Bayreuth. Professor Agassiz (in the Catalogue Raisonné des Echinides) enumerates a manuscript species of M. Desor, from the white chalk of Martignies near Guievrain, which, judging from the short notice here given, appears to approach still more nearly that before us.

CIDARIS CLUNIFERA, Agassiz, Echin. Suiss. ii. 68. t. 21. f. 20, 23.

Spines only, but exactly agreeing with the representations of those of the Neocomian species (from Neuchatel in Switzerland), to which we have referred it.

Subcretaceous limestones near Torres Vedras and Alenquer.

CIDARIS GLANDIFERA, Goldfuss, Pet. Germ. p. 120. t. 40. fig. 3?; Agass. Echin. Suiss. t. 21*a*. fig. 9?

A single spine, approaching so closely to those figured by Goldfuss and Agassiz that we scarcely dare to separate it as a species. It differs slightly in having the tuberculated ridges less granular centrally and below. The *Cidaris glandifera* is a coral rag species. Mr. Sharpe's specimen is from the subcretaceous limestone of Alenquer.

There are fragments of a third *Cidaris* from this limestone at Ourem.

ECHINOPSIS? SUBUCULUS, sp. nov. PL. XXV. fig. 2.

E.? testâ subconicâ, areis ambulacralibus angustis, assulis omnibus tuberculis primariis mediocribus ornatis, tuberculis distantibus, in areis ambulacralibus seriebus duabus, in areis interambulacralibus seriebus quatuor dispositis, verrucis minimis sparsis.

Breadth $\frac{5}{12}$ inch; height $\frac{3}{12}$ inch.

I have referred with doubt to the genus *Echinopsis* the fragment of a little Urchin from the subcretaceous limestone of Figueira, in which the tubercles are so worn as to render the determination of the perforated or non-perforated character of their summits doubtful. The pores are ranged in a single series. The general aspect of the species so strikingly resembles that of *Galerites subuculus*, that, were it not for some of the plates of the ovarian disk still remaining, we should scarcely have been warranted in placing the specimen among the *Echinidæ*. The species of *Echinopsis* to which it approaches are from the nummulitic limestone and the white chalk. It is very distinct however from either.

PLATE XXV. fig. 2 *a*. Natural size.

Fig. 2 *b*. Magnified.

DIADEMA LUSITANICUM, sp. nov. PL. XXV. fig. 4.

D. testâ depressâ, areis ambulacralibus latis, interambulacrales subæquantibus; assulis omnibus tuberculo primario ornatis, tuberculis omnibus ferè æqualibus, tuberculis secundariis nullis, verrucis minimis inter tubercula sparsis, in areis ambulacralibus paucis; margine incisuris conspicuis.

Breadth $\frac{7}{12}$ inch; height $\frac{3}{12}$ inch.

The body of this *Diadema* is much depressed, so as to give the outline a flattened-out form. The ambulacral and interambulacral areas are nearly equal in width, and both bear two ranges of prominent, but not very large, primary tubercles, perforated on their summits and with crenulated bases. The areolæ of the tubercles are wide, leaving but narrow spaces for the tertiary granules, which are scattered, separate, and rather unequal, and have mostly mammilliform bases. The granulated space between the two rows of tubercles in each interambulacral segment is much wider than that in each ambulacral one, where it is reduced to a nearly single undulating line of unequal granules. The mouth is rather large, and has ten conspicuous notches with reflexed edges around its margin.

I cannot identify this species with any of those figured by Agassiz and others. It approaches however *Diadema superbum*, Agassiz (Oxford clay of Switzerland), *D. florescens*, Agassiz (coral rag of Besançon), and *D. complanatum*, Agassiz (Kelloway rock, coral rag, and Oxford clay of France).

The specimen described is from the subcretaceous limestone of Mamarosa, four leagues south-east of Aveiro.

Plate XXV. fig. 4 *a*. Natural size.

Fig. 4 *b*. Magnified.

Diadema rude, sp. nov. Pl. XXV. fig. 3.

D. testâ depressâ, areis ambulacralibus mediocribus, assulis omnibus tuberculo primario magno ornatis, tuberculis arearum interambulacralium majoribus, tuberculis secundariis nullis, verrucis minimis inter tubercula sparsis, paucis; ore lato, margine inciso.

Breadth $\frac{6}{12}$ inch; height $\frac{5}{24}$ inch.

A species quite distinct from the last, though in a very dilapidated condition. The body is depressed with rather rounded sides. The ambulacral areas equal in width about two-thirds of the interambulacrals. Both are studded with large and conspicuous tubercles on prominent bases, those of the interambulacral plates largest. The spaces between the tubercles have few and scattered granules. The mouth is very wide and its margin notched, but not conspicuously.

The *Diadema placenta* of Agassiz, from the coral rag of Soleure, has affinity with this species. Mr. Sharpe's specimen is from the subcretaceous limestone of the Praia de Maçams near Cintra.

Plate XXV. fig. 3 *a*. Natural size.

Fig. 3 *b*. Magnified.

Toxaster Couloni? Agassiz.

A much-injured specimen of an Urchin, too closely allied to be separated without better materials from the species so named by Agassiz, was found by Mr. Sharpe in the subcretaceous limestone of Figueira. It appears to differ in having its vertex more central. *Toxaster Couloni* is a Neocomian species, and all its near allies are either Neocomian or Gault species.

BRISSUS (HEMIASTER) SUBDEPRESSUS, sp. nov. PL. XXV. fig. 6.

B. (H.) testâ subcordatâ, supernè depressâ, areâ anali elevatâ, carinatâ, lateribus tumidis, posticè truncatâ; ambulacris lateralibus latis subæqualibus, impressis, areâ post-orali lanceolatâ.

Length $\frac{10}{12}$ inch; breadth $\frac{9}{12}$ inch; height $\frac{6}{12}$ inch.

This little species is allied to the *Spatangus Bufo* of authors, and to the *Micraster minimus* of Agassiz, but differs from them and from most of its described congeners in the depression of its back, which has only a very slight and gradual slope from the elevated posterior interambulacral area. The ambulacra are rather broad, and seated in not very deep depressions with rounded sides. Each linear series of double pores in the antero-lateral ambulacra of the largest specimen examined consists of twenty-seven pair, and in the postero-laterals of twenty-four. The sides and under surface were rough with spinigerous tubercles. The mouth is placed not very far forward, and the spinous space behind it is lanceolate in shape. The anal extremity is suddenly truncated, but with a slight obliquity. Young specimens are much more depressed than old ones.

It is not unlikely that this may be one of the numerous species of *Hemiaster* enumerated by Desor in the 'Catalogue Raisonné des Echinides'; but without figures or descriptions to guide us, it is impossible to recognize mere names with localities only appended, or notices so brief as to be useless.

This *Brissus* occurs in the subcretaceous limestone of Figueira and is apparently plentiful. Its affinities are with cretaceous species, especially those of the Gault.

Along with it a form is found with longer and narrower ambulacra and greater tumidity of the sides. This is possibly distinct, but the specimens examined are too fragmentary for determination. It occurs also at Mamarosa.

PLATE XXV. fig. 6 *a* & *b*. Usual form.

Fig. 6 *c*. Variety.

BRISSUS SCUTIGER. PL. XXV. fig. 5.

B. (Brissopsis) testâ cordatâ, tumidâ, supernè subdepressâ, areâ anali convexâ, declivente, lateribus prominentibus, posticè rotundato-truncatâ, ambulacris antero-lateribus lanceolatis impressis, postero-lateralibus ovatis-oblongis, areâ post-orali triangulari.

Breadth $1\frac{1}{12}$ inch; length $1\frac{1}{12}$ inch; height $\frac{8}{12}$ inch.

The outline of this *Brissus* is cordate, truncate posteriorly, tumid at the sides. The true apex is nearly central, and from that point the back declines gradually in front and rises suddenly posteriorly, but the rise is very brief, and then there is a gradual gently curved declension to the oval, not very large anus. The hinder extremity is truncated steeply with a slight obliquity. The ambulacra are placed in gentle, but conspicuous depressions, all equally deep. The antero-lateral ones widely diverge, the postero-laterals but slightly comparatively. In the former there are about thirty pairs of pores in each row, in the latter about twenty-four. The former are broadly lanceo-

late, the latter oblong. All are surrounded by a very slightly sinuated fasciole inclosing a shield-like space. The surface of the test is covered with scattered tubercles surrounded by rings of granules; the interspaces are minutely granulated. The subanal fasciole is indistinct and distant from the anus. The post-oral spinous space is broadly triangular.

This handsome species is from the upper beds of hippurite limestone, of the valley of Alcantara, near Lisbon.

Remarks on ZAMITES GRAMINEUS. By J. MORRIS, Esq.

ZAMITES, Brong. (*Otozamites*, Braun.)

Z. GRAMINEUS. *Cycadites*, Phillips, Geol. York. i. tab. 10. f. 2, var. *Mundæ*, nob. PLATE XXVI. fig. 7 *a* & 7 *b*.

The vegetable impressions in the shale associated with the coal from Cape Mondego, belong to a small group of fossil fronds referred by some authors to the family Cycadeæ (*Zamites*), and by others to the Ferns (*Odontopteris* and *Otopteris*); the relation however of some species arranged in the latter genera is still considered doubtful.

The Mondego specimen may be provisionally referred to that section of the genus *Zamites*, Brong., of which *Z. Bechei*, Brong., and *Z. brevifolia*, Braun, are the types, consisting of pinnate fronds, with more or less linear-lanceolate pinnæ, having an auricled or semicordate base, and for which M. Braun has proposed the name *Otozamites**.

The species from Cape Mondego appears to be identical with the *Zamites gramineus*, sp. Phillips, as regards the general form of the frond and pinna; but the veins are more numerous in the Portuguese specimen than in the figure given in the 'Geology of Yorkshire' (vol. i. tab. 10. fig. 2).

It may be thus described:—

Frond pinnate, pinnæ alternate, oblique, linear-elongate and slightly falcate at the apex, auricled at the base or semicordate; veins fine, numerous, equal, dichotomous, and somewhat parallel or even slightly flabellate; rachis slender, striated?

The pinnæ are distant from each other about half the width of a pinna, and attached by the lower half of the base; the veins radiate in the auricle. On the same slab of shale is an impression of a smaller specimen, and which is probably only the young or not fully developed frond of the same species; but it differs in having the pinnæ shorter, more approximate and obtuse, and in this respect somewhat resembles the *Zamites brevifolius*, Braun.

PLATE XXVI. fig. 7 *a*. Frond of the natural size.

Fig. 7 *b*. A leaflet magnified.

* These forms are characteristic of the Jurassic series, being chiefly found in the lias and lower oolite.

EXPLANATION OF THE PLATES.

Plate XIV. to Plate XIX. Fossils from the Hippurite limestone.

PLATE XIV.

Fig. 1. Arca Olisiponensis.
Fig. 2. Artemis elegantula.
Fig. 3. Cardium corrugatum.
Fig. 4. Cardium Olisiponense.

PLATE XV.

Fig. 1. Cyprina globosa.
Fig. 2. Cyprina cordata.
Fig. 3. Diceras Favri.

PLATE XVI.

Fig. 1 to 3. Caprinula Boissyi.

PLATE XVII.

Fig. 1 & 2. Caprinula brevis.
Fig. 3 & 4. Caprinula Doublieri.

PLATE XVIII.

Fig. 1 & 2. Caprinula d'Orbignii.
Fig. 3. Avicula Olisiponensis.
Fig. 4. Perna fragilis.

PLATE XIX.

Fig. 1 & 2. Exogyra Olisiponensis.
Fig. 3. Pecten inconstans.

PLATE XX.

Fossils from the upper division of the Subcretaceous series.

Fig. 1. Rostellaria Costæ.
Fig. 2. Corbula Costæ.
Fig. 3. Artemis inelegans.
Fig. 4. Ostræa prælonga.
Fig. 5. Terebra obconica.
Fig. 6. Turritella Cintrana.
Fig. 7. Turbo Mundæ.
Fig. 8. Pyramidella sagittata.
Fig. 9. Diceras Favri.

Plates XXI. to XXIV. Fossils from the lower division of the Subcretaceous series.

PLATE XXI.

Fig. 1. Tellina Sobralensis.
Fig. 2. Corbula Edwardi.
Fig. 3. Artemis cordata.
Fig. 4 & 5. Astarte discus.

PLATE XXII.

Fig. 1 to 3. Cyprina securiformis.
Fig. 4. Trigonia Lusitanica.
Fig. 5. Mytilus Morrisii.

PLATE XXIII.

Fig. 1 & 2. Gervilia Sobralensis.
Fig. 3 to 6. Gervilia Fittoni.
Fig. 7 & 8. Perna Lusitanica.

PLATE XXIV.

Fig. 1 & 2. Perna polita.
Fig. 3. Pecten Lusitanicus.
Fig. 4. Ostræa pustulosa.
Fig. 5. Natica Lusitanica.
Fig. 6. Nerita turbinata.
Fig. 7. Neritina bicornis.

PLATE XXV.

Fossil Echinidæ from the Hippurite limestone and Subcretaceous beds.

Fig. 1. Echinus Olisiponensis, from the Hippurite limestone.
Fig. 2. Echinopsis subuculus, from the subcretaceous beds.

1.a

1.b

1.c

2.b

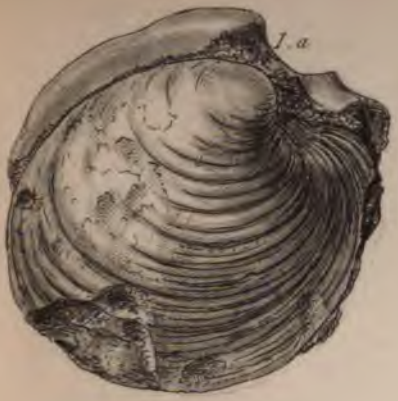
2.a

3.a

3.b

4.b

4.a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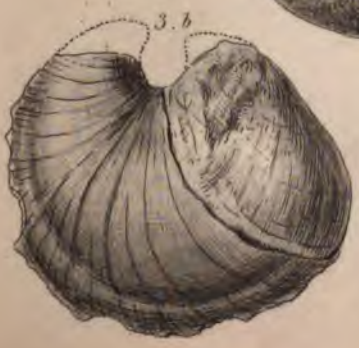
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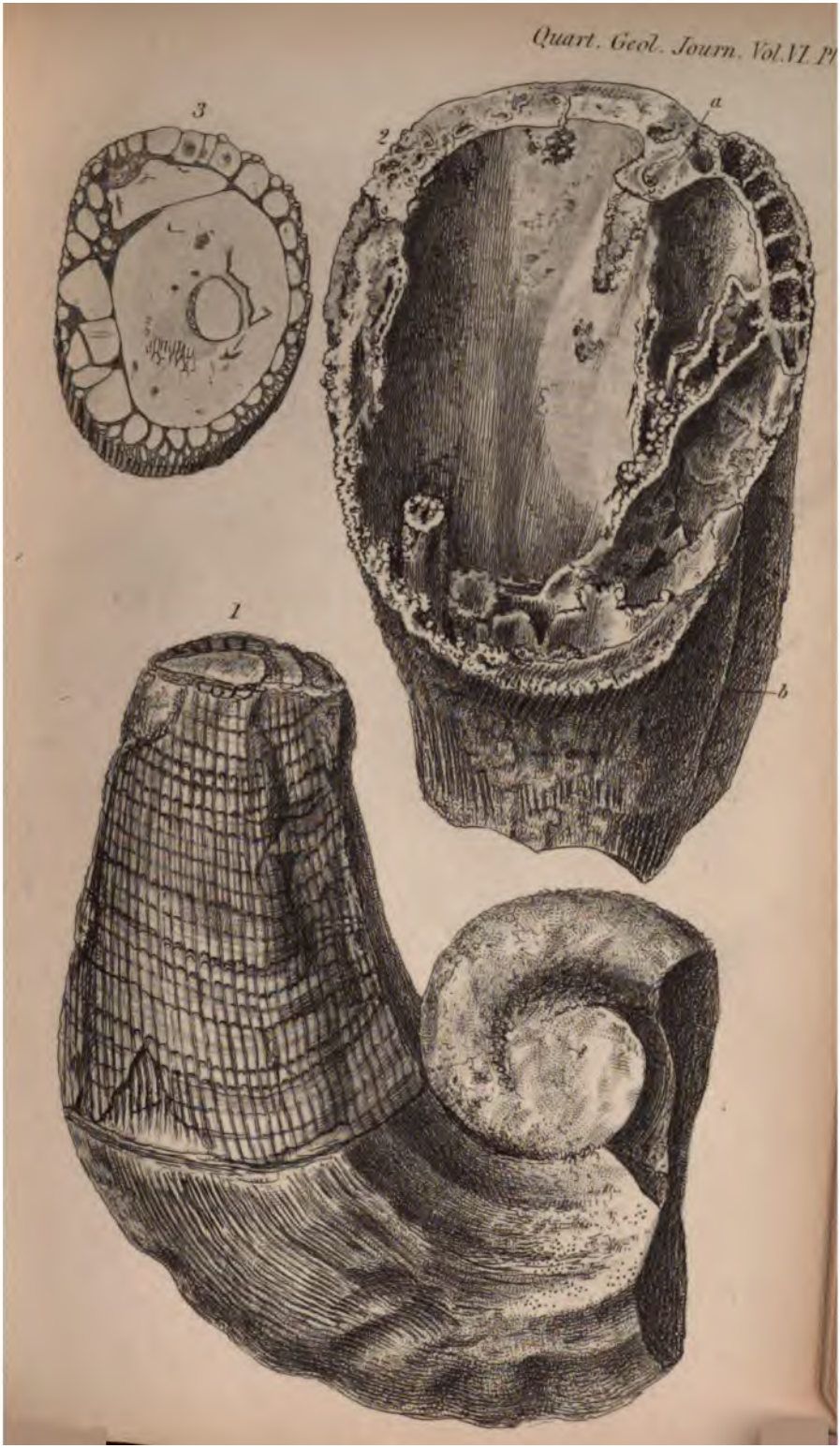
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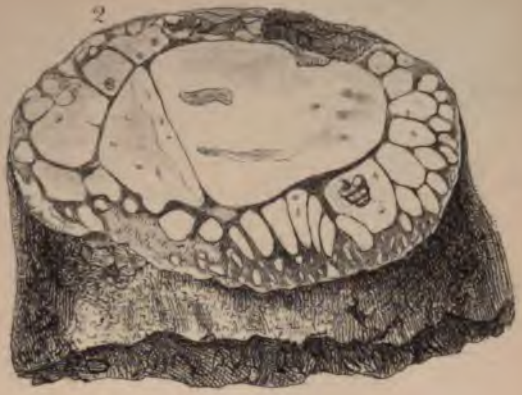
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3 a

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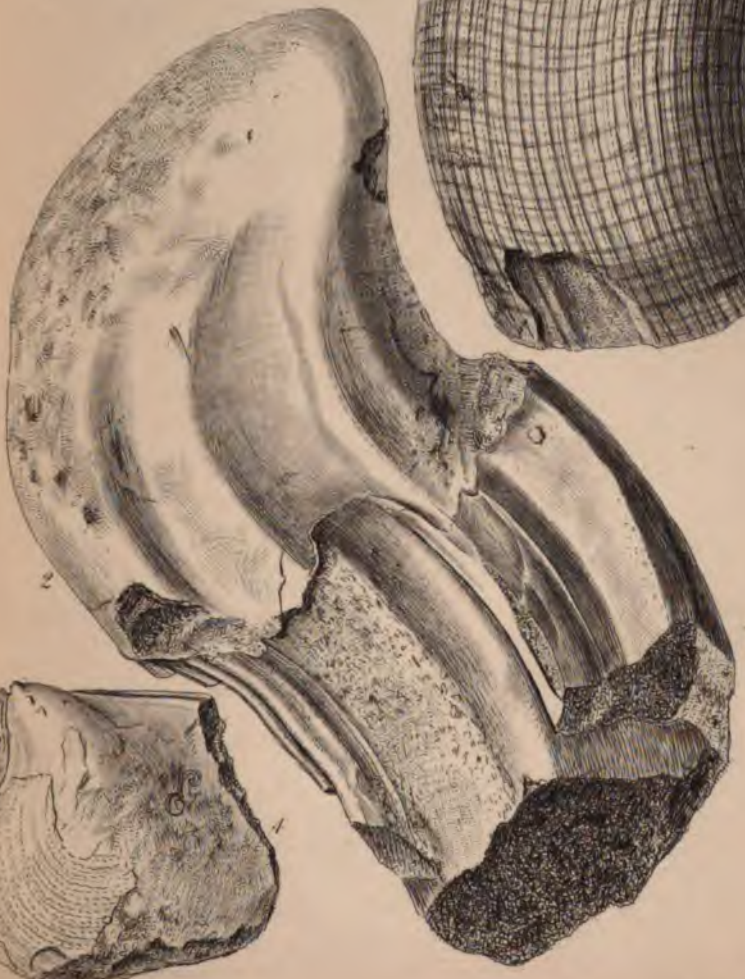
4

3.a

3.b

1



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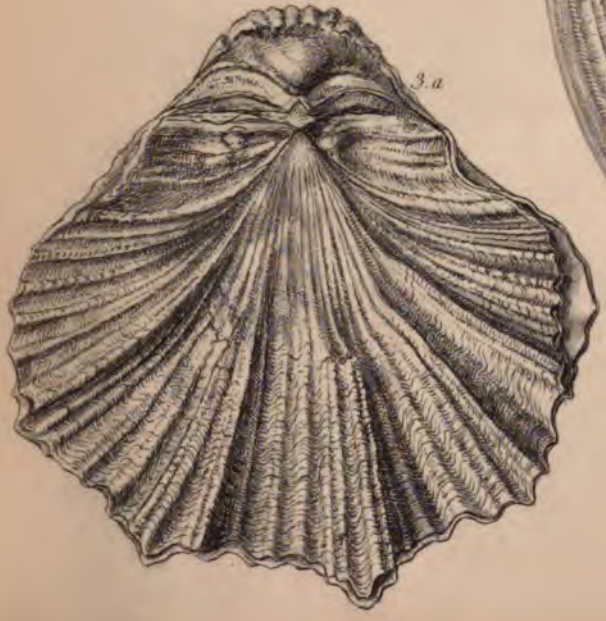
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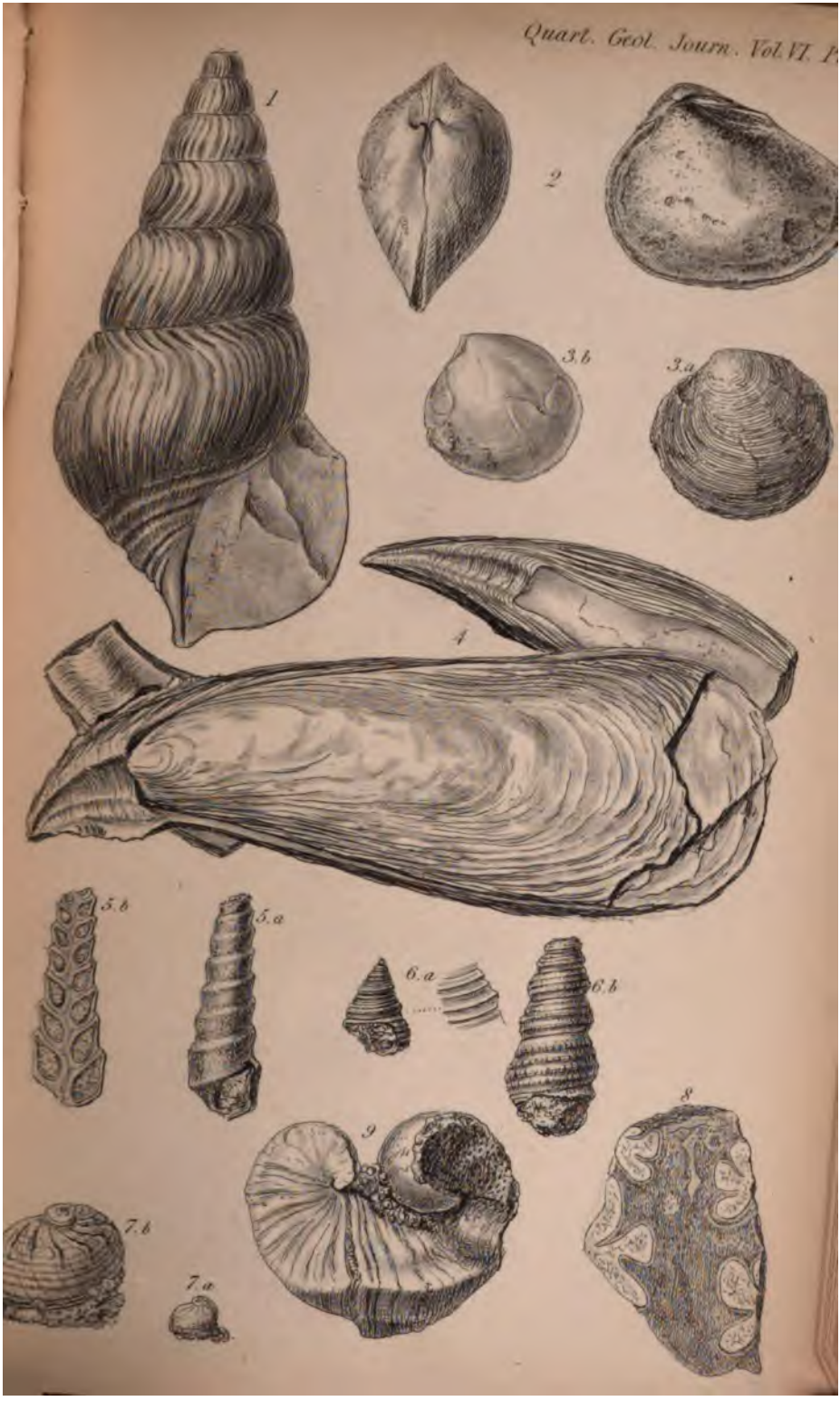
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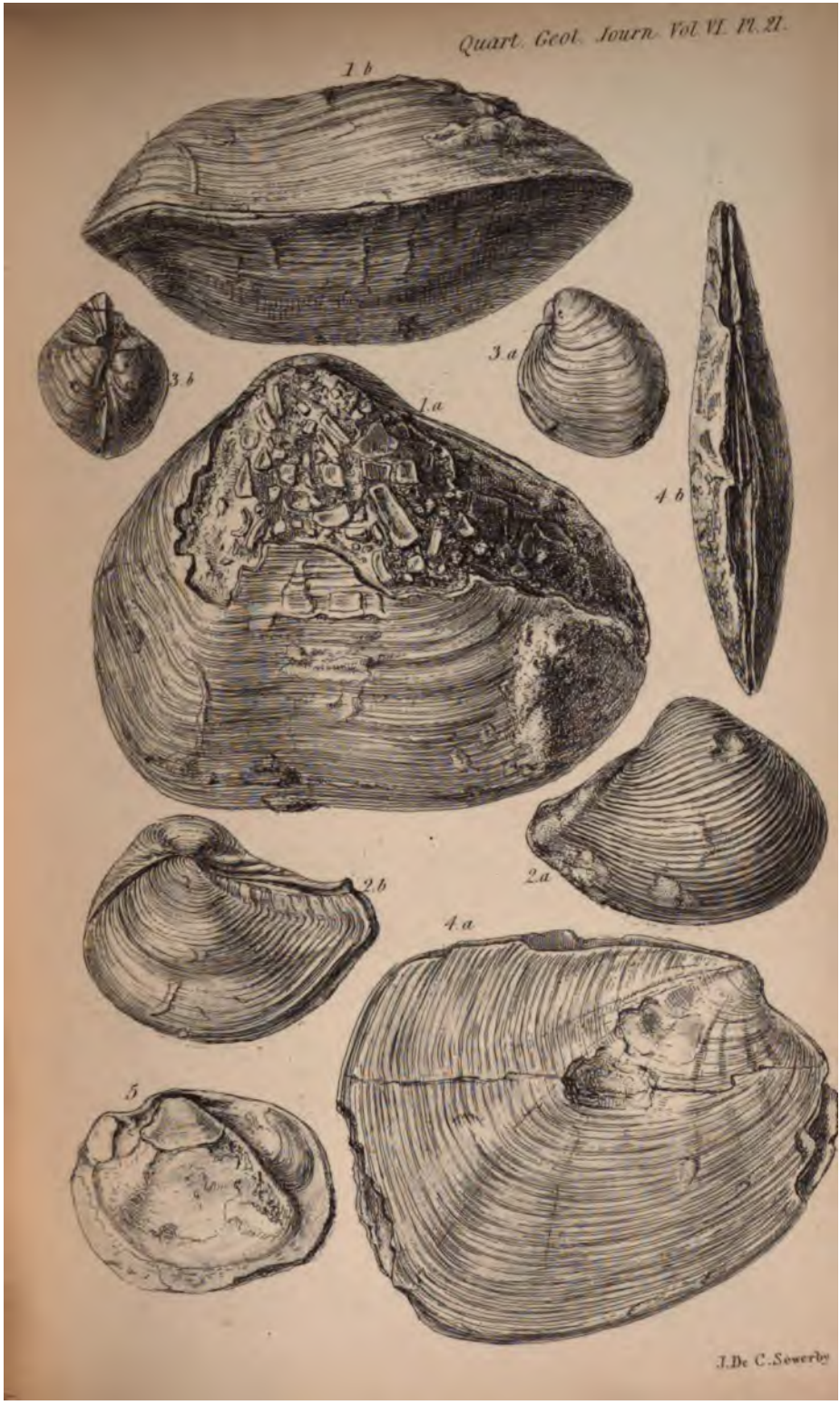
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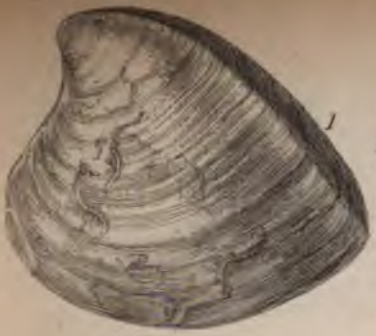

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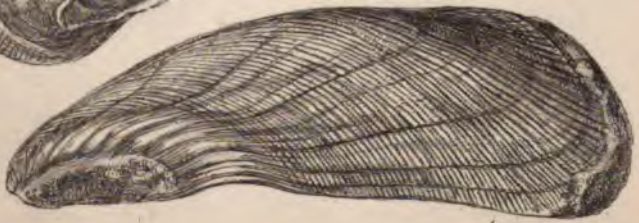

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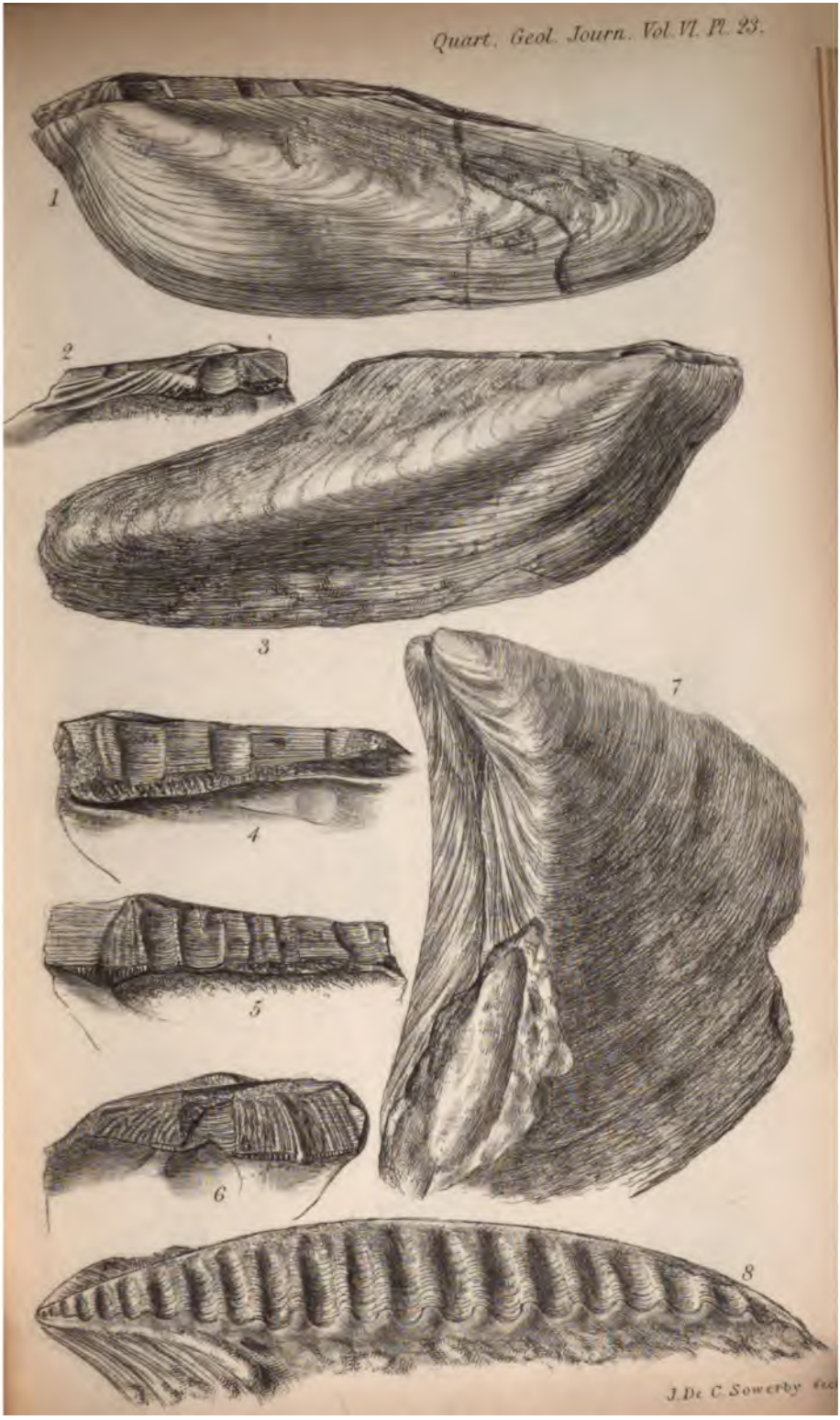
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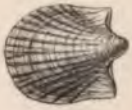

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Fig. 3. Diadema rude, from the subcretaceous beds.
Fig. 4. Diadema Lusitanicum, from the subcretaceous beds.
Fig. 5. Brissus scutiger, from the Hippurite limestone.
Fig. 6. Brissus subdepressus, from the subcretaceous beds.

PLATE XXVI.

Fossils from the Jurassic Series.

Fig. 1. Mytilus Beirensis.
Fig. 2. Spirifer Beirensis.
Fig. 3. Terebratula Beirensis.
Fig. 4 & 5. Dianchora bicornis.
Fig. 6. Turrilites Beirensis.
Fig. 7. Zamites gramineus.

DECEMBER 5, 1849.

Count Achille de Zigno, of Padua, Robert Aglionby Slaney, Esq., M.P., Ernest Noel, Esq., William Lee, Esq., and Cornelius Nicholson, Esq., were elected Fellows of the Society.

The following communications were then read:—

1. *On the Age of the* UPPER TERTIARIES *in* ENGLAND. By SEARLES V. WOOD, Esq., F.G.S.

[This paper was withdrawn by the author with the permission of the Council.]

2. *On the Occurrence of* MAMMALIAN REMAINS *at* BRENTFORD. By JOHN MORRIS, Esq., F.G.S.

THE discovery of mammalian remains in the vicinity of Brentford has long been well known to geologists. It is more than thirty years since Mr. Trimmer obtained a valuable collection from this district. An account of these remains and of the conditions under which they were found, was published with illustrations in the 'Philosophical Transactions' for 1813. In 1838 I collected from an excavation, for the reservoir of the water-works near Kew Bridge, numerous horns and bones of the ox and deer, and bones of the elephant; traces of lignite also, but no remains of shells, were observed. I should not, therefore, have laid before the Society the following remarks, had not the progress of the railway-works in that neighbourhood exposed some sections, which not only fully corroborated previous observations, but afforded some new facts connected with the history of the deposit, as well as a considerable number of mammalian bones, for the preservation of which we are indebted to the active zeal of Mr. Thomas Layton, jun.

The sections alluded to occur about 100 yards north of Kew Bridge, where a branch or rather loop line of the South-Western and Windsor Railway passes under the high road at the entrance to Brentford. The section here given occurs north of the bridge, where the entrance to the station is completed.

This section gives the principal features of the deposit, as exposed in the deepest part of the railway cutting, which extended about one-

Section of Railway Cutting at Brentford.

1. 1. Vegetable mould; 1 foot.
2. 2. Brickearth, a fine brownish loam; 4 feet.
3. 3. Fine sand, mostly stratified and obliquely laminated, with occasional wavy and irregular veins of small gravel; 6 feet.
4. 4. Sand, with light-coloured clay and irregular gravel, containing bones; 6 to 8 inches.
5. 5. Ferruginous gravel and sand, with patches of clay; 1 foot.
6. 6. Clayey sand and sandy gravel, with occasional large flintstones, partly ferruginous at the upper part, containing bones and shells; 1 to 2 feet.
7. 7. Ferruginous sand and gravel; about 6 inches.
8. 8. Light clayey sand and ferruginous gravel, with boulders of quartz, granite, rock with ammonites, &c., also bones, &c. of ox, deer, &c.; 6 to 7 feet.
9. 9. London clay.

third of a mile, and presented great variations in the order and relative thickness of the sands and gravel, which pass into one another in a very irregular manner.

No remains were, I believe, found in the brick earth and sand (2 and 3); the sand (3) throughout its whole extent was stratified and obliquely laminated, some of the layers being more ferruginous than the others, and occasionally interstratified with veins of small gravel; the ferruginous gravel (5) is of less regular thickness, the upper surface being sometimes eroded and the hollows subsequently filled with a coarse greyish sand and light clay (4), containing bones; the clayey sand (6), also containing bones, is the chief depositary of the shells, which were generally in a perfect state of preservation, the Anodons retaining their usual brown epidermal covering.

The chief mass of the ferruginous gravel (7) consisted of rounded and angular chalk-flints of various sizes; but occasionally intermixed with them were a few pebbles and small boulders of other rocks, as London clay septaria with *Teredinæ*, indurated greensand, sand rock with ammonites, fragments of pyritical ammonites (Oxford clay?), coarse reddish sandstone, white quartz, granite, &c.

The bones, although occurring in all the layers below No. 3, were most abundant in the lowest stratum; on one side of the railway, a vein of sand, containing shells, was observed, intercalated with this gravel bed. Below the gravel bed is the London clay upon which the whole deposit rests, but the depth of the clay was variable and not accurately determined.

The section above given, although differing in minor details, presents similar general characters to those recorded by Mr. Trimmer as occurring in the clay-pits examined by him, one of which is more than a mile distant; there can be little doubt, therefore, of the synchronism of this deposit; the later excavations have also afforded, with the exception of the hippopotamus, similar mammalian remains, with the addition of the great cave tiger and reindeer.

The shells were but few in number in this locality as compared with the more eastward deposits in the Thames valley. After a careful search, and with the assistance of Mr. Layton, I could only find the following eight recent species:—

Bithynia impura.	Limnæus stagnalis.
Succinea amphibia.	Pisidium amnicum.
Valvata piscinalis.	Cyclas cornea.
Limnæus auricularis.	Anodon anatina.

Not even fragments of *Cyrena trigonula* and *Unio littoralis*, now extinct (at least in England), were observed, although these species are common at Ilford, Grays, Erith, Stutton, &c., where they are associated with a large number of our present indigenous, fluviatile and terrestrial mollusca.

From the general features, both physical and fossil, of this deposit, which has now been traced over a considerable area in the neighbourhood, I am inclined to consider it as resulting from fluviatile action, and that at a period when a river, far more deep and extensive than the present stream, flowed along the valley. Even allowing the base of the deposit to be level with high-water, a river of considerable depth must have existed, to have accumulated and arranged twenty feet of solid materials, and that not in a very violent manner, for scarcely any of the bones exhibit the least trace of attrition, most of them being perfect, and many belonging to the same individual; thus rendering it nearly certain that they could not have been drifted from any great distance, but were probably the remains of those animals which lived and died not far from the banks of that stream, where they subsequently became entombed in the same deposit with the fluviatile mollusca.

The mammalia associated together in this deposit consist of the elephant, rhinoceros, hippopotamus, aurochs, short-horned ox, red deer, reindeer, and the great cave tiger or lion; the discovery of the latter animal (a well-preserved ulna of which has been identified by Prof. Owen) is highly interesting; hitherto, I believe, the remains of this carnivore have (with one exception, viz. that of North Cliff, Yorkshire) been obtained only from the ossiferous caverns.

The occurrence of the reindeer is a point equally interesting and important, not only from its remains being but rarely found in this country (two instances only being cited by Prof. Owen), but from the association of this arctic form with other mammalia generally considered indicative of a warm climate. Thus, its co-existence with the great cave tiger, from the presumed tropical character of the genus to which the latter belongs, might be regarded as somewhat

anomalous; on this point however Prof. Owen *, speaking of the genus *Felis*, justly observes, "There is no genus of mammalia in which the unity of organization is more closely maintained, and in which, therefore, we find so little ground in the structure of a species, though it may most abound at the present day in the tropics, for inferring its special adaptation to a warm climate."

With regard to the relative age of this deposit, I had formerly considered it† as synchronous with the numerous mammalian beds which occur throughout the valley of the Thames. The evidence, however, is not very satisfactory, inasmuch as the presence of pebbles apparently derived from the drift might lead to the inference of its being posterior to that period, and the absence of the *Paludina marginata*, *Cyrena trigonula*, and *Unio littoralis*, may distinguish it from the beds at Ilford, Grays, Erith, &c.

Still, perhaps, sufficient value has not been assigned to certain specific mammalian remains of the later tertiary deposits, as tests of their relative position; nor can we feel the full importance of slight specific differences until we are acquainted with the true and exact value of the succession of the different groups of mammals, during the more recent geological changes; and the geologist should use great caution in marking the exact bed from whence the remains that he submits to the comparative anatomist are derived, even though he obtain them from the same valley. Independently however of these considerations, there is a singular fact, which must not be overlooked as connected with the present subject, viz. that it is generally along those valleys where the present drainage of the country is effected that we find the most extensive deposits of mammalian remains and recent shells; and consequently very little alteration can have taken place as regards the physical configuration of the country since the period of their deposition.

List of Mammalia found at Brentford‡.

Elephas primigenius.	Cervus tarandus.
Bison priscus.	Rhinoceros tichorhinus.
Bos longifrons.	Hippopotamus major.
Cervus elaphus.	Felis spelæa.

* British Fossil Mammalia, p. 162.

† Mag. Nat. History, 1838, p. 539.

‡ Mr. Thomas Layton, jun., has presented a collection of the mammalian remains to the British Museum.

DONATIONS

TO THE

LIBRARY OF THE GEOLOGICAL SOCIETY,

November 1st to December 31st, 1849.

I. TRANSACTIONS AND JOURNALS.

Presented by the respective Societies and Editors.

American Journal of Science. Second Series, vol. viii. no. 24.

——— Philosophical Society, Proceedings. Vol. v. no. 43.

Athenæum Journal, November and December 1849.

Chemical Society, Quarterly Journal. No. 8.

Cornwall, Royal Institution of. Thirtieth Annual Report, 1848.

France, Société Géologique de, Bulletin. Deux. Série, tome vi. feuilles 27–34.

Indian Archipelago, Journal of the. Vol. iii. no. 9.

Irish Academy (Royal). Transactions, vol. xxii. part 1. Proceedings, vol. iv. part 2.

Leeds Philosophical Society. 28th and 29th Annual Reports.

Philadelphia, Academy of Natural Sciences of, Journal. New Series, vol. i. part 3. Proceedings, vol. iv. nos. 9 and 10.

Philosophical Magazine, November and December 1849. *From R. Taylor, Esq., F.G.S.*

II. GEOLOGICAL AND MISCELLANEOUS BOOKS.

Names in italics presented by the Authors.

Brongniart, A. Tableau des genres de Végétaux Fossiles.

Burmeister, Dr. Hermann. Die Labyrinthodonten aus dem bunten Sandstein von Bernburg, zoologisch geschildert. Erste Abth. Trematosaurus.

Dana, J. D. United States Exploring Expedition, during the years 1838–42. Geology, with Folio Atlas of Plates.

Hausmann, J. F. L. Studien des Göttingischen Vereins Bergmännischer Freunde. Band 5. Heft 3.

Hennessy, Henry. Abstract of Papers read before the Geological Society of Dublin.

Hogg, John. Remarks on Mount Serbal, being the true Mount Sinai, with Map.

Morris, John. Note on the Genus Siphonotreta, with a description of a new species.

———. Observations on Mr. Hancock's paper on the Excavating Sponges.

Pictet, F. J., et W. Roux. Description des Mollusques Fossiles qui se trouvent dans les Grès verts des Environs de Genève. 2nde livraison, Gasteropodes.

Stevenson, W. F. The Composition of Hydrogen and the Non-decomposition of Water demonstrated.

Zigno, Achille de. Atti verbali della Sezione di Geologia, Mineralogia e Geografia, estratti dal volume degli atti della IV. Riunione degli Scienziati Italiani, ch' ebbe luogo in Padova nel Sett^re^ 1842.

———. Introduzione allo Studio della Geologia. Part 1.

———. Sulla Giacitura dei Terreni di Sedimento del Trivigiano Memoria.

———. Nota intorno alla Non-Promiscuità dei Fossili fra il Biancone e la Calcarea Ammonitica delle Alpi Venete.

———. Sul Terreno Cretaceo dell' Italia Settentrionale Osservazioni.

———. Sopra due Fossili rinvenuti nella Calcarea dei Monti Padovani Memoria.

Zoology of the Voyage of H.M.S. Samarang, during the years 1843–46. No. iv. part 2, and no. 5. *From Messrs. Reeve.*

THE

QUARTERLY JOURNAL

OF

THE GEOLOGICAL SOCIETY OF LONDON.

PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

DECEMBER 19, 1849.

The following communication was read:—

On Craters of Denudation, with Observations on the Structure and Growth of Volcanic Cones. By Sir CHARLES LYELL, Pres. Geol. Soc.

IN the first edition of my 'Principles of Geology,' published in 1830 (vol. i. ch. 30), I explained the grounds of my objection to the theory previously advanced by Baron von Buch to account for the origin of the Caldera of Palma, the Gulf of Santorin, and other bowl-shaped cavities of large dimensions, for which he proposed the name of "Craters of Elevation." I regarded the circular escarpments surrounding these vast cavities as the remnants of cones of eruption, the central parts of which had been destroyed, and I conceived that the removing cause had been chiefly, if not wholly, engulfment.

In the second edition of my 'Principles,' published in 1832, or two years later, I discussed more particularly the origin of the single deep gorge, which in Palma, Barren Island, and other so-called elevation-craters, forms a breach in the circular range of cliffs, surrounding the central cavity. This ravine or narrow passage I attributed "to the action of the tide during the gradual emergence from the sea and upheaval of a volcanic island" (ch. 22. vol. i. p. 452), and I at the

Fig. 1.—*View of the Isle of Palma, and of the entrance into the central cavity or Caldera.—From Von Buch's "Canary Islands."*

Fig. 2.—*Map of the Caldera of Palma and the great ravine, called "Baranco de las Angustias."—From a Survey of Capt. Vidal, R.N.*, 1837.

same time alluded to its analogy to the single passage leading into the lagoons of many annular coral islands or Atolls.

Although I then distinctly announced this theory in regard to such narrow ravines, the idea had not occurred to me that the same denuding power of the waves and tides, which were thus appealed to as adequate to remove the rocks once filling such deep gorges, must of necessity have exerted a like action on the walls of the craters themselves. I well knew from the excellent description published by Von Buch of Palma, an island to which I specially alluded, that the long and deep chasm called Baranco de las Angustias, which alone breaks the continuity of the rocks enclosing the caldera, and was bordered on both sides by steep cliffs, was not less than between six and seven miles in length, being at its upper extremity 2000 feet or more in depth. I ought therefore, in consistency, to have inferred, that the same ocean, which I supposed to have stood successively at various levels, and in the course of ages to have ground down and carried away so vast a volume of rock, from this channel, must during the same long period have excavated a part of the hollow once occupied by similar and equally destructible materials.

By referring to the annexed map, fig. 2, from Capt. Vidal's 'Survey of Palma,' the reader will observe that the sea cliff at Point Juan Graje, 780 feet high, now forming the coast at the entrance of the great ravine, is continuous with an inland cliff which bounds the same ravine on its north-western side. No one will dispute that the precipice at the base of which the waves are now beating, owes its origin to the undermining power of the sea. It is natural therefore to attribute the extension of the same cliff to the former action of the waves exerted at a time when the relative levels of the island and the ocean were different from what they are now.

Of late, after fully reconsidering the subject, I have come to the conclusion that the origin of a great part of the Caldera of Palma was probably due to denudation, and that the same holds true of other analogous cavities, such as are seen in Teneriffe, and many volcanic islands, so well described by M. von Buch in his classical work on the Canaries. Santorin in particular, which has been selected as furnishing the best type of a crater of elevation, owes, I believe, the chief part of the extension of its circular gulf to denudation, the whole crater together with the surrounding rocky islands having subsided bodily since the denudation, so as to be now half submerged in the waters of the Mediterranean.

Before I proceed to treat more in detail of this and other volcanos, I shall offer a few preliminary remarks, to prepare the geologist for the reception of the views about to be proposed. In the first place it is admitted, that many of the volcanos, in which these large crateriform hollows exist, have been formed wholly or in part beneath the level of the sea; 2ndly, the quantity of solid rock assumed by me to have been worn down and carried away through a narrow channel by the waves and currents (as the islands emerged) is by no means great, when contrasted with the masses removed from many elliptical areas, which have been called valleys of elevation, such as the Wealden, or

the smaller valley of Woolhope. The latter has been described by Sir R. Murchison, and more recently by Mr. Phillips*. It is $4\frac{1}{2}$ miles in diameter, and resembles in size as well as in some of its leading features the Caldera of Palma, the beds, in the boundary cliffs encircling the excavated space, dipping in all directions outwards, and the cliffs for that reason retaining more easily their steepness or verticality.

3rdly. If the crater of a submarine volcano be upraised and begin to emerge, the sea will still flow into it on its lowest side, and the circular basin will then be filled and emptied alternately by the flux and reflux of the tide, or by the rise of water blown into the opening by prevailing winds, and then falling again as soon as this force ceases to act, by which means a passage will be kept open, the crater being scoured out like estuaries which have narrow entrances. On the efficacy of this last mode of aqueous erosion I must particularly insist, as it aids us more than any other in comprehending the theory of denudation-craters. The Basin of Mines in the Bay of Fundy illustrates the manner in which a large bay, communicating with the ocean by a narrow strait, may be filled and half-emptied every tide, so that the waves and currents may sweep out in the course of centuries a vast volume of mud and sand, and produce on all sides of the bay long ranges of cliffs annually undermined, several hundred feet perpendicular, some composed of soft red marl, others of hard quartzose grit, and others of columnar basalt. The Bay of Fundy it is true would not present, if it were upraised and laid dry, so circular a hollow as the so-called crater of elevation, but there are numerous coves on a part of the coast of Dorsetshire which are as perfectly circular, if not more so than the Gulf of Santorin or the Caldera of Palma, and in which the single breach effected by the sea on one side is not larger in proportion to the entire girdle of encircling cliffs. These cliffs moreover, which every geologist attributes exclusively to the denuding action of the sea, are precipitous, and most lofty at the head of the bay or farthest from the entrance, where they consist of inclined strata of chalk. Lulworth Cove, which is 1300 feet across, is the most perfect example (see fig. 3). In this case the hardness of

Fig. 3.

Coast of Dorsetshire.

* Murchison, Silurian System, Part I. p. 428, and J. Phillips, Mem. of Geol. Survey, vol. ii. p. 167.

the Purbeck and Portland strata prevents the waves and tides from breaking down and widening the seaward barrier, and the comparative softness of the vertical or highly inclined beds between the barrier and the chalk at the head of the bay promotes the enlargement inside the entrance.

4thly. But there are certain valleys in Australia, described by Mr. Darwin, which from their depth, the steepness of their boundary cliffs, and the narrow gorges by which the sea has entered to hollow them out, afford perhaps a still more striking explanation of the mode of operation, to which I shall refer in great part the origin of such craters as Palma, the Gulf of Santorin, and others of similar large dimensions. I allude to those valleys near Sydney in New South Wales, by which the great platform of sandstone, 1200 feet thick, is penetrated. The traveller, says Mr. Darwin, when walking over the summit plains, finds himself suddenly at the brink of a continuous line of lofty cliffs, so perpendicular, that he can strike with a stone the trees growing at the depth of between 1000 and 1500 feet below him. At the distance of several miles he beholds the opposite line of cliff, rising up to the same height with that on which he stands, and formed of the same horizontal strata of sandstone. So continuous are the bounding lines of cliff, that to descend into some of these valleys it is necessary to go round twenty miles; but what is still more remarkable, these valleys, although several miles wide in their upper parts, generally contract towards their mouths to a mere chasm, impassable to man or beast. Thus the gorge of the Cox river is only 2200 yards wide, and about 1000 feet in depth. Mr. Darwin at first asked himself whether the mass of stone removed from these great amphitheatrical depressions, had not subsided vertically; but was compelled to abandon this notion on considering the narrow promontories which projected from the platforms into the valley. He was also struck with the resemblance of the inland basins or bay-like recesses to the present bold sea-coast, where there are similar recesses forming fine harbours, connected with the sea by narrow mouths, sometimes not more than a quarter of a mile in width, the cliffs being formed of similar sandstone.

5thly. It must also be remembered that in the coasts of volcanic islands, such as Palma, Santorin, St. Helena, and others, there are lofty cliffs of basaltic and other igneous rocks, often traversed by dikes which have been formed by the undermining action of the sea, and are still wasting away. Mr. Darwin has particularly dwelt on the enormous cubic mass of hard rock pared off by the swell of the Atlantic from the coasts of St. Helena, where there are perpendicular cliffs from 1000 to 2000 feet in height, consisting of basaltic strata traversed by dikes (p. 91). In this island also, as well as in St. Jago and Mauritius, he has observed in his volume on Volcanic Islands, p. 93, that the ring of basaltic mountains forming what is commonly called "the crater of elevation," must once have been nearly or quite continuous, although now broken. Some very wide breaches have, he observes, been evidently effected by the denuding action of the waves. All these islands, he concludes, have been elevated in mass.

It will be seen therefore that to account for the excavation of certain large crateriform cavities in some of these same islands, I am merely introducing a force, which is already acknowledged to have been most energetically exerted in destroying extensive masses of rock formerly environing the spaces called elevation-craters.

Having said thus much of the denuding or removing power, I shall next offer a few prefatory remarks on the mode of origin of the dome-shaped volcanic masses, of which I consider the boundary rocks of every denudation-crater to be the basal remains. Mr. Scrope, writing in 1827, attributed the formation of a volcanic cone chiefly to matter ejected from a central orifice, but partly to the injection of lava into dikes, and to that force of gaseous expansion, the intensity of which in the central parts of the cone is attested, he said, by the local earthquakes which often accompany eruptions*. But it was reserved for M. E. de Beaumont, seven years later, to point out that the extent, uniform thickness, and compact structure of many sheets of basaltic lava, which constitute the flanks of many volcanic cones, such as Etna and Somma, leave very little doubt that they were originally poured out on a surface, much less inclined to the horizon than the angle at which they now slope. To the same observer we are indebted for most valuable researches into the laws governing the flow of lava streams, the result of which he published after his visit to Etna in 1834. In his memoir on that mountain he endeavoured to prove that the numerous up-filled fissures or dikes are the evidence and measure of the elevation of the distended volcanic mass, consisting of sheets of lava and alternating conglomerates, and that the whole mountain is probably undergoing upheaval bodily from time to time, as often as it is traversed by star-shaped cracks, such as occurred during the eruption of 1832.

In the later edition of my 'Principles†' I referred to the labours of M. de Beaumont, and admitted that a greater part of the beds exposed in the precipices of the Val del Bove were "originally less inclined, some of them perhaps much less so than now." At the same time I attributed the change of position to the "successive fracturing, distension and upheaval of the cone," not to a sudden upthrow. Whether I still underrated the amount of unequal elevation by which certain beds are believed to have been tilted and changed from their pristine horizontality, I know not, but I feel as convinced as ever that I was right in continuing to reject the hypothesis of elevation-craters, of which MM. de Beaumont and Dufresnoy have been the able and strenuous advocates. When repeating in my different publications the objections previously urged by myself and others to the theory of Von Buch, I always cited the argument so strongly insisted upon by M. Constant Prévost, that if beds of non-elastic materials had yielded suddenly to a violent pressure directed from below upwards, we should not find a circular cavity with an even and unbroken rim, but an irregular opening where many rents converged, and these rents

* Geological Transactions, 2nd Series, vol. ii. p. 341.
† See edition of 1847, p. 401.

would now be seen breaking through the walls of the crater, and widening as they approached the empty central space*. Instead of any such open rents being visible in the walls of the Caldera of Palma, and in analogous crateriform cavities, we invariably find dikes or upfilled fissures, in which, as well as in tortuous veins, often forming a reticulated mass, the melted matter was clearly consolidated before the boundary cliffs were formed. The origin therefore of all such rents, numerous as they are, was wholly antecedent in date to the whole movement assumed as the cause of the elevation-crater. I have also in every edition of my works uniformly contended, in common with Messrs. Scrope, C. Prévost, and others, that in mountains like Etna, Mont Dor, and the Cantal, we must look to that area where we now find the greatest thickness of lava and fragmentary ejections as the chief and permanent source of the alternating lavas, tuffs, scoriæ, and conglomerates composing the volcanic cone. The increase of the cone, so far as it consists of such superimposed igneous products, I compared to the exogenous growth of a tree, and in Etna and some other volcanos a series of superimposed sloping beds has been piled up successively to a thickness of more than 4000 feet. We may call the injection of lava, and the distension and upheaval caused by the hydrostatic action of imprisoned vapours, to which M. de Beaumont has justly attributed much greater importance than I had previously conceded, or even than Mr. Scrope had assumed, the *endogenous* growth of the mountain. The intensity of this last-mentioned mode of increase is much greater in the more central than in the marginal parts of a volcano. For this reason we perceive near the margin or base of the cone that the lava and beds of scoriæ, as they gradually thin out, become intersected by fewer and fewer dikes, until these at length entirely cease to appear. Not only the number, but the size or width also of such dikes may often be seen to augment as we approach nearer and nearer to the central axis of the cone. Other generalizations on the origin and growth of cones and craters I shall defer to the sequel, as they will be best explained when I am commenting on the structure and probable mode of formation of particular volcanos.

Palma.

To one of the most remarkable of these, the island of Palma, I shall first allude. Von Buch has given us a graphic picture of what seems to be the most splendid and perfect example yet discovered of a huge and deep cavity, surrounded on all sides by a circular range of precipices which are 4000 feet in height, the beds dipping outwards in all directions from the centre of the void space, which is about six geographical miles in diameter. The sloping beds consist chiefly of basalt alternating with conglomerates, composed in part of *rolled* masses of similar basalt. Here, therefore, we seem to have evidence of the subaqueous origin of a portion at least of the volcanic accumulation, while the highest part of the cone may have raised

* Principles of Geology, ch. 24. Mém. de la Soc. Géol. de France, tome ii. p. 91.

itself, like Stromboli, and been exposed to the power of the waves. The inclination of the beds corresponds to that of the external slope of the island, being greatest towards the central hollow axis, and less steep near the sea. The intersecting dikes and veins are more and more abundant as we approach the crater, and therefore are most numerous where the slope of the beds is greatest. This is seen by aid of a transverse section of the entire succession of beds obtained in the cliffs bounding the one deep baranco which extends from the sea-coast to the crater. The origin of this deep ravine, a phænomenon, says Von Buch, common to all "craters of elevation," and which recurs in the Great Canary, the island of Amsterdam, Barren Island, and, as we shall presently see, in Santorin, is left wholly unexplained by the hypothesis of sudden upheaval, unless we are prepared to assume that the same engulfment which swallowed up the central mass once filling what is now the hollow axis of the cone, has extended to one side and one side only of the encircling zone of rock (see figs. 1 & 2, p. 208). Had there been several such gorges interrupting the circular and solid girdle which encloses the caldera, it might have been argued with some plausibility that such openings were due to the fracture of a non-elastic mass, which, however slowly upraised, could not expand and stretch, because even the less compact beds were fortified by ribs of the unyielding stony substances constituting the dikes.

According to Von Buch, the mass upheaved in Palma fell back into the middle of the crater *, but sections seem wanting to show that the nature and structure of the bottom of the great hollow, where the ground rises very considerably in the centre of the caldera, are such as to lend countenance to this conjecture. The theory of denudation briefly stated at the commencement of this paper may explain not only the excavation of the caldera, but may account for its enormous size; and what is still more satisfactory, it absolutely requires the existence of a great baranco through which the abstracted rocky materials or the missing portions of the cone have been swept out in the form of mud, sand and gravel. To refer the evacuation of the Caldera of Palma to explosion is inadmissible, for the same reason that M. de Beaumont has very properly rejected a similar hypothesis in regard to the Val del Bove on Etna, viz. because if so vast a volume of solid matter had been blown out into the air, it must when it fell down again have formed a dense bed of fine dust and angular fragments of stone, such as does not envelope the surface or exterior slope of the island. Sections of such an envelope would have been seen in the ravines or barancos, some of them 500 feet deep, which radiate towards all points of the compass, from the rim of the caldera to the sea, without however interrupting by their upper or shallower extremities the continuity of that rim. As to the origin of these numerous barancos, M. von Buch is of opinion, that the torrents now flowing in some of them, even when the snow melts in the higher parts of the truncated cone, are too inconsiderable to cause them. He sup-

* Description des îles Canaries, p. 285. French edition, 1836.

poses them to have been produced when the island was suddenly upraised, an hypothesis which I regard as inadmissible, because they never intersect the rim of the escarpment. If on other grounds we conclude that the elevation of Palma from the sea was gradual, we are bound to reflect whether the waves may not have contributed as well as torrents acting on rocks of unequal hardness to produce such ravines.

Santorin.

After I had indulged in the above speculations in respect to the origin of the Caldera of Palma, it occurred to me that the circular gulf or crater of Santorin offered a serious objection to the theory of denudation, because the boundary cliffs of the Gulf plunge suddenly into very deep water. It is clear that while the land and sea stand at their present relative levels, the bottom of a crater 1000 feet deep could never have been hollowed out by the denuding force of waves and currents: but learning from my friend Capt. W. H. Smyth, that a new survey of Santorin had been recently executed, under the direction of Capt. Graves, I obtained, through the kindness of Capt. Becher, of the Hydrographical department of the Admiralty, an unpublished chart, in which the soundings around and between this group of islands are laid down with great minuteness. Capt. Smyth also allowed me to consult a paper recently communicated to the Geographical Society by Lieut. Leycester, who has been actively engaged, together with Lieut. Mansell, in the late survey. From these sources I have derived data by which it will appear that the case of Santorin, so far from militating against, is, on the contrary, strongly confirmatory of the denudation theory, besides throwing no small light on the mode in which new volcanic mountains are gradually formed in the centres of many craters of denudation. The largest of the three islands surrounding the circular gulf of Santorin is called by Lieut. Leycester, Thera (see Map, fig. 4). It is of a horse-shoe form, and has an external coast-line of eighteen miles. It is three miles wide from east to west, and, as MM. Boblaye and Virlet ascertained, consists of volcanic matter, with the exception of its southern part, where Mount St. Elias (fig. 4, D), 1887 feet high, occurs, being composed of limestone and argillaceous schist. The volcanic mass is quite independent of these older formations, and abuts against them. It is made up of alternating beds of trachytic lava, tuff, and conglomerate, which, as M. Virlet has shown, have a gentle dip outwards from the centre of the Gulf, towards which they terminate abruptly in a steep and often perpendicular cliff. That these beds, and similar ones occurring in the other two eastern islands, Therasia and Aspronisi, are the lower portions of a great cone or flattened dome, the centre of which has disappeared, was the opinion arrived at by MM. Virlet and Boblaye, in the French 'Expedition of the Morea.' In the cliffs, says M. Virlet, the separate masses of trachyte and obsidian are seen to mould themselves into the inequalities of previously existing surfaces formed by fragmentary and conglomerate beds. Neither the solid nor the incoherent masses constitute wide-spreading sheets, but are dis-

Map of Santorin in the Grecian Archipelago, from a Survey in 1848, *by Capt. Graves, R.N. The soundings are given in fathoms.*

Fig. 4.

A. Shoal formed by submarine volcanic eruption in 1650.
B. Northern entrance.
C. Mansell's Rock.
D. Mount St. Elias, 1887 feet high.

Fig. 5.—*Section of Santorin, in a N.E. and S.W. direction, from Thera through the Kaimenis to Aspronisi.*

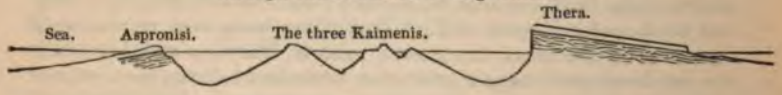
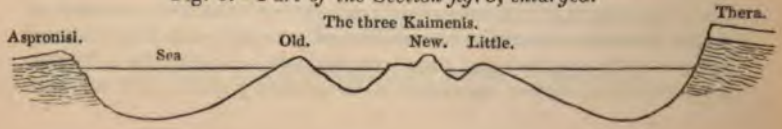


Fig. 6.—*Part of the Section fig.* 5, *enlarged.*



continuous and dove-tailed into each other, except one grand deposit of white tufaceous conglomerate, which forms the capping of all the islands. M. Virlet found that the vesicles or pores of the beds of trachyte were lengthened in the several directions in which they would naturally be drawn out, had they flowed as melted matter towards different points of the compass from the summit of a cone, the axis of which once occupied the centre of the gulf. From the structure, irregularity, and interrupted nature of the beds, and their moderate dip, not exceeding in Thera three or four degrees, there seems no reason to assume that they have undergone any change from their original position, except such as may have arisen from general upward and downward movements of the whole island.

The length of the outer coast-line of the three islands taken together is about thirty miles. Aspronisi is not more than a mile in circuit, and only 300 feet high. It is surrounded by dangerous shoals for a distance of about a third of a mile, as if it had recently wasted away by the action of the sea; and in the geological chapter before cited of the 'Expedition of the Morea,' it is stated that the waves are constantly preying on the marginal cliffs of the three islands, so as to enlarge the intervals between them *. That these islands were once united has been the conclusion of every geographer and geologist who has seen them; but the late survey by Capt. Graves may be said to have set the question for ever at rest. The subaqueous rim of the crater has been traced, first from Cape Acrotiri in Thera to Aspronisi, the depth of water varying from five to ten fathoms, and then from Aspronisi to Therasia, where there is the same depth, one spot, called Mansell's shoals (fig. 4, C), being no more than nine feet under water.

Throughout the circuit of these two lines of shoal, constituting the unbroken subaqueous rim of the crater, the water was found to deepen suddenly on the inside, or towards the gulf; but in the third channel, called the northern entrance (fig. 4, B), about a mile wide, between Therasia and the nearest part of Thera, a remarkable breach is discovered in the continuity of the submarine walls of the great bowl. Near the land on both sides the water is shallow for a certain distance, as if the cliffs had wasted away. Then there is a plunge to 100 fathoms, and in the middle of the passage no less than 195 fathoms, or 1170 feet. This deep ravine in the bed of the sea is significantly spoken of by Lieut. Leycester, as the "door into the crater." It is evidently the "portillo" of Santorin, or its "Baranco de las angustias." It is the single chasm through which, when the Santorin archipelago stood more than 1000 feet higher, the contents of the vast crater of denudation were swept by the sea; and it is a remarkable fact, that its depth precisely agrees, to within a few inches, with the greatest depth discovered, after minute soundings, in any part of the gulf. It is also important to remark, that outside the islands, where the soundings deepen much more gradually than in the inside of the gulf, they reach in some places, as for example about two miles south-west of Aspronisi, to depths of 250 and 260 fathoms, showing that the Gulf

* Expédition de Morée, vol. ii. p. 259.

of Santorin, deep as it is, is still shallower than some of the adjoining parts of the Mediterranean, and might, if upraised, present a dry crater connecting by a chasm with the sea.

The greatest depth of the crater or gulf according to the late survey was found to be between the shores that are highest; that is to say, between that part of Thera where Merivali is situated and the opposite cliffs of Therasia, which are about four miles distant. Here the soundings reached 213 fathoms. The height of the escarpment at Merivali is 1171 feet, that of the high land in Therasia 936 feet, the cliffs on both sides above water and below being very steep and in great part perpendicular. If therefore, says Lieut. Leycester, the crater were empty, the observer looking down into it from Merivali would behold a frightful abyss 2449 feet in depth, the bottom consisting generally of reddish or brownish clay, and the opposite side, or that of Therasia, would be only 235 feet less deep. A vast circular cavity, nowhere less than 1200 feet deep, would be seen to be eighteen miles in circumference, the encircling cliffs broken in one place, and one only, by a ravine 1170 feet deep. The walls of the great crater would be nearly twice as high on the north-east as on the south-west side, on the whole very uniform in outline; but at Scaurus a narrow promontory would jut out from the steep cliff, about one-third of a mile into the gulf.

In the middle of this great caldera (the waters being drawn off) a single volcanic mountain would appear, bearing the same relation to the surrounding deep sea and circular escarpment which the Peak of Teneriffe bears to its moat and bastion, as described by Von Buch, or which the active volcano in the centre of Barren Island bears to the marine channel and outer girdle of rocks by which it is surrounded. This central mountain (see sections figs. 5 & 6, p. 216) is about five miles and a half in circumference at its base, and is surrounded on all sides by deep water. Its longest diameter is about two miles, in a direction from north-east to south-west. It has five summits, which spring from a ridge at the height of about 1000 feet from the bottom of the crater. Three of these summits, called the Kaimenis, rear their heads above the present level of the waters. The north-eastern, called the Little Kaimeni, or little burnt island, is 222 feet above water, formed by eruption in 1753. There is a cone on it having a crater eighty feet deep, and on the north side of it a considerable bank, of large blocks of lava and ashes. The top of this cone is 1550 feet above the base of the mountain. The middle, or New Kaimeni, was produced during eruptions in 1707 and 1709. It was composed at first of two parts, which were afterwards united. Its summit consists of a cone, which rises 351 feet above water. Its sides slope at an angle of 33°, and its shape, well delineated by Bory St. Vincent in plate 37. fig. 2 of the Morea Expedition, is precisely that of cones of single eruption in Auvergne, or on the flanks of Etna. The crater on the summit is eighty yards in diameter, according to Lieut. Leycester, and the highest point of the cone is 1629 feet above the bottom of the abyss. The south-western island, or the Old Kaimeni, is 328 feet above water, or twenty-three feet lower than the highest of the other peaks. The channel which

separates it from the New Kaimeni is in one part 100 fathoms deep. The two other summits spoken of are submerged cones, one occurring on the north and the other on the east of the Kaimenis, the northern peak being twenty-four fathoms under water and 1158 feet high, the eastern peak twenty fathoms, giving it a height of 1251 feet above the bottom of the crater. Their summits are flat. They spring from the same ridge as the Kaimenis, and the whole mountain with its five summits nearly bisects the gulf in a north-east and south-west direction, a direction not assigned to the Kaimenis in maps published previously to the late survey (see Map, fig. 4. p. 216).

From a history of the successive formation of different parts of this central volcano, or volcanic ridge, we derive the knowledge of facts of great geological importance, for we are taught that the Kaimenis owe their present elevation not only to the heaping up of cones of fragmentary matter, but to the bodily though partial upheaval of portions of the trachytic mass, bearing on its surface a thin layer of pumiceous ash, containing marine shells. The rise of this bed of pumice, first called the White Island, in the year 1707, is on record, and it has been examined of late years by Mr. Edward Forbes, who made a collection of the marine shells contained in it, among which were both univalves and bivalves, of the genera *Pectunculus*, *Arca*, *Cardita*, *Trochus*, and many others, all recent species of the Mediterranean *, in a fine state of preservation, and implying that the sea-bottom on which they lived, when enveloped by a fall of ashes, was between twenty and thirty-five fathoms in depth. The state of the bivalves, their shells double with their valves closed, with the epidermis remaining, indicated that they had been suddenly destroyed. We know therefore from the habits of these mollusca, as observed by Mr. Forbes in the Mediterranean, that an upheaval of at least 220 feet was required to bring them up to the level of the sea, above which they now rise to the height of five or six feet. This bodily upheaval of a certain mass of ashes does not appear to have affected the other two islands equally, if at all, at the same period, still less to have extended to the outer islands; for if so, such ports as Phira, built on the water's edge, on a talus of fallen fragments from the vertical cliff, would have been carried upwards. We have here then an indisputable proof, in the Gulf of Santorin, that in the gradual reconstruction of a volcanic mountain in what was previously the original centre of eruption, large masses of solid matter may be lifted up in mass, 150 or 200 feet, and sustained at that height, while other parts of the volcano in the immediate vicinity do not participate in the movement. This power of the lava or gases to carry upwards, to a height of 200 feet or more, a stratified deposit, which M. Virlet considered as having floated like cork on the top of a denser fluid, is a phænomenon which may perhaps aid us in comprehending how, in some steep isolated hills, like the Puy Chopine in Auvergne, the volcanic mass may have been uplifted, together with large fragments of the granite on which it reposed, as MM. von Buch, Le Coq, and Daubeny have held. We learn that when the new island Neokaimeni

* British Association Report for 1843.

was formed in 1707, it went on increasing irregularly, and sometimes was lowered on one side while it gained height on the other. At different periods also during the growth of the island, isolated rocks rose up in the sea at different distances from its shore, some of them appearing and disappearing at intervals. There were many evidences of eruption before a visible crater was at length formed, so that we may infer that an intumescent mass of pasty or fluid trachyte was forcing up the top of the hill, as we see lava-currents, when they meet with an obstruction, swell up because they are encased by and confined within a solid exterior, the sides of which often slope at an angle of more than 40°. The large open rents seen on the surface of the Old Kaimeni or Hira attest the distension of that island, during the injection of lava beneath it. In a word, the whole history of these central islands shows that they owe their origin to the successive and intermittent action so characteristic of volcanos, and lends no support to the hypothesis of a single paroxysmal explosion, by which either a gigantic mountain or crater can be formed at one effort. Had the denuding action of the sea never removed the central portions of the ancient cone, all those masses of brown trachytic lava and pumice which have now gone to the production of the central volcano, called the Kaimenis, would have been expended partly in the filling of fissures with melted matter, forced upwards, partly in the outpouring of lava, and ejection of scoriæ from a permanent central vent. For in some cases, as in the Sandwich Islands, we see craters much loftier than that which crowns Etna emit streams of lava of enormous volume. But it happens more commonly in volcanos, that, as they gain in height, the pressure of the central column of lava overcomes the resistance offered by the sides of the cone, so that the latter give way at some points. There can therefore be little doubt that a large proportion of the materials now composing the Kaimenis would, if the great dome had remained entire, have been emitted in the form of lateral cones. Had this occurred, the volcanic strata now encircling the Gulf of Santorin would have been intersected by veins and dikes, whereas none of the geologists who have visited Santorin make any allusion to such dikes, and Mr. Edward Forbes tells me he observed none of them in any of the three outer islands, Thera, Therasia, and Aspronisi. We must consider therefore these three masses as the basal remains of a large dome or cone, so far removed from the original centre of eruption as not to have been subject to injection from below.

As the theory of denudation requires us to suppose in the case of Santorin an oscillation of level, that is to say, first the gradual rise of a cone of submarine origin and secondly its partial submergence, it is worthy of remark that Lieut. Leycester states that on the east side of Thera there is a road now twelve fathoms under water, which formerly led from Perissa to Camari, and which was above water before the earthquakes of 1650, in which year a volcanic eruption occurred in the sea about three miles and a half north-east from Cape Colombo in Thera, where vapour and flames were thrown out and the sea was covered with pumice, and where after some months a shoal (fig. 4, A,

p. 216) was left having ten fathoms water over it. This shoal Captain Graves surveyed, and the soundings were found to deepen in all directions, demonstrating the existence of a submarine conical eminence. Lieut. Leycester was also told of houses seen at the bottom of the sea on the east of Thera, near the site assigned for the ancient Eleusis; and a similar statement was made of ruins under water, at the base of the steep cliffs of Therasia; but as on this coast inside the gulf the water deepens very suddenly from the base of the cliffs, an earthquake may have thrown down some buildings into the sea. It is therefore unsafe to draw any positive conclusion in favour of subsidence from such data.

When we reflect on the oscillations of land which have occurred within the last eighteen centuries, on the site of the Temple of Serapis near Naples, we may well imagine much greater movements of 1000 or 2000 feet to have happened in the course of the geological period during which Santorin may have been exposed to denudation.

I may observe however, that if a general upward movement should now recommence in this archipelago, so that the crater should emerge at the rate of a few feet or yards in a century, the waves would have power to tear down the rim where it is now perfect at a slight depth under water, namely between Therasia and Aspronisi and between the latter island and Thera. The same force which is now denuding the cliffs of those islands would readily undermine rocks of diversified and partly incoherent composition, during a continual change of level from century to century. The effects of this slow waste would appear in the form of wide breaches in the outer wall or ring of volcanic rocks, so that the condition of Santorin would approach much more nearly than now to the broken basaltic escarpments of St. Jago and Mauritius, as described by Mr. Darwin.

There has been some controversy as to whether the fundamental argillaceous schist seen in the south-eastern part of Thera, or the main island, crops out also in Therasia; but if so, it would not affect the theory of denudation above proposed; for we must conclude with Mr. E. Forbes that the original volcano of Santorin was formed in the bed of the Mediterranean, on which the limestone mass and argillaceous schist of Mount St. Elias, now 1887 feet above the sea, formed a submarine mountain, against which the south-eastern base of the great cone abutted. It is therefore very possible, though we have as yet no certain data for the fact, that the same pre-existing inequalities of the sea-bottom may cause similar ancient rocks to crop out in a part of Therasia.

Island of St. Paul.

The volcanic island of St. Paul, situated in the midst of the Indian Ocean, lat. 38° 44′ south, long. 77° 37′ east, and surveyed in 1842 by Captain Blackwood, R.N., may serve in some degree to aid us in conceiving how such an archipelago as that of Santorin may have been formed (see figs. 7, 8, 9). In that portion of the volcano, probably a very insignificant part of the whole, whether in height or area, which at present emerges above the level of the wide ocean, we have a crater

Fig. 7.

Map of the Island of St. Paul, lat. 38° 44′ *S., long.* 77° 37′ *E., surveyed by Capt. Blackwood, R.N.*, 1842.

Fig. 8.

View of the Crater of the Island of St. Paul.

one mile in diameter surrounded by steep and lofty cliffs on every side, save one, where the sea enters by a single passage nearly dry at low water. In the interior of the small circular bay or crater there

Fig. 9.

Side view of the Island of St. Paul (N.E. side). Nine-pin rocks two miles distant. Captain Blackwood, R.N.

is a depth of thirty fathoms or 180 feet. The surface of the island slopes away in every direction from the crest of rocks encircling this crater. The highest peak is 820 feet above the level of the sea. If we suppose considerable oscillations of level to occur by gradual movements of upheaval and subsidence, the sea which has had power to wear away part of the island and produce lofty and perpendicular cliffs, would continue to keep open the single entrance, and as it deepened it would also enter and undermine the walls of the crater, so as to widen its area. Although by this means what is now the central and higher portion of the island would be entirely destroyed, still high interior cliffs would be produced, and a section of part of the volcano, now submerged, would be laid open in the deep ravine excavated on the eastern or lower side of the island. On every other side the rim of the enlarged crater or caldera might remain unbroken.

Somma.

The evidence of Somma having been originally a submarine volcano, has appeared more and more satisfactory in proportion as recent observations have been multiplied. MM. von Buch and Dufresnoy affirm that the tuff which surrounds the mountain to the height of 1900 feet above the sea, contains marine shells analogous to those which I found at the height of 2605 feet on the neighbouring volcanic island of Ischia, all of which, except one, were of species now living in the Mediterranean. As some of the component beds of lava preserve throughout large spaces a uniform texture and are inclined at an angle of 30°, it is inferred by MM. von Buch, De Beaumont, and Dufresnoy, and probably with good reason, that they have now a much steeper slope than they had originally. On such a slope, they observe, such wide and compact sheets of lava could never have been formed. If, instead of imagining the superimposed tuffs and lavas to have swelled up like a great bubble according to the elevation-crater hypothesis, we suppose that they gained their additional steepness when they were traversed at successive periods by the dikes and veins with which they are now reticulated, we may account for the high angle of their dip, while at the same time the multitude of dikes, so far exceeding those seen at any other neighbouring point of the Phlegræan fields, points to this spot as the grand focus of eruption in ancient as well

as in modern times. It explains, in short, why Somma, like Vesuvius, towers above all the other volcanic eminences.

The summit of the submarine dome may probably have had a gentle slope on all sides, not exceeding perhaps 8° or 10°, although we have yet to learn in regard to subaqueous lavas, whether, moving through a denser and more resisting medium than the atmosphere, they may not spread in wider sheets and assume a compact texture, or an inclination exceeding that required to produce the same effects when their course is subaërial. The more general absence of ravines and valleys in the bed of the sea, where volcanic eruptions occur, would promote the spreading out of the melted matter in an even sheet, and the pressure of the incumbent water would check the expansion of the gases and prevent the mass from acquiring a more open and cellular texture. When M. Pilla had attentively observed in 1837 and afterwards in 1845 the similarity of the disposition of the beds in Somma and the modern Vesuvius, he could not resist the conclusion that both were formed in an analogous manner, and he rejected the theory of elevation-craters as applied whether to the one or the other*. At a later period however M. Pilla admitted, that a sheet of basalt 1000 metres above the sea in Somma, inclined at an angle of 24° and very compact, proved that there had been an upheaval of the mass†; an opinion which is compatible with the views embraced in this paper respecting the gradual increase of a cone by internal and external additions. That a vast number of eruptions were concentrated within a narrow space is assumed by M. Dufresnoy himself, who considers the dikes of Somma as having been the feeders of successive beds or sheets of lava. It was not overlooked that a long series of eruptions occurring within very confined limits must in the course of time have given rise to a conical mass composed in this instance of superimposed fragmentary and porphyritic beds. Such a result however was opposed to Von Buch's hypothesis, and in order to escape from it in this and other analogous cases, a very arbitrary hypothesis was resorted to;—a depression in the bed of the sea was assumed to have pre-existed, in which the beds of lava and scoriæ accumulated in horizontal masses, and the position of the mass thus formed was finally inverted, the convex side being made to project upwards instead of downwards.

Somma is the remains of a crater about three miles in diameter, the walls of which we may infer, from a passage in Plutarch, were before the great eruption of Vesuvius in the year 79, very perfect and entire, except on one side, where there was a single breach. Dr. Daubeny has shown in his comments on the passage, that when Spartacus encamped his gladiators in the crater in the year 72, Clodius the Prætor besieged him there, and keeping this single entrance carefully guarded, let down his soldiers by scaling ladders over the steep precipices which surrounded the cavity, now called the Atrio del Cavallo, where the insurgents were encamped‡. Originally therefore Somma had the usual form of craters of denudation, a single ravine interrupting the circuit

* Pilla, cited by Archiac, Hist. des Progrès de la Géol. tom. i. p. 538.
† Archiac, ibid. p. 518. ‡ See Daubeny's Volcanos, p. 216.

of the walls, and the fossa grande was perhaps a continuation of this ravine, and was hollowed out by the sea as the mountain was slowly raised above its level; but to what extent in this instance an original crater of eruption may have been widened by the sea, I will not venture to speculate.

Monte Nuovo.

MM. von Buch and Dufresnoy regard this cone and crater as consisting of solid beds of white tuff previously horizontal, which were suddenly upheaved in 1538, so as to dip away in all directions from the centre with the same inclination as the sloping surface of the cone itself. To me it appears, that in addition to all the arguments derived from the absence of rents in the walls and rim of the crater, and the uniformity of structure of the whole funnel-shaped cavity from top to bottom, we have direct historical testimony against such an hypothesis. The cone is 440 English feet high and a mile and a half in circumference, the crater within a few feet as deep as the cone is high. The dip of the beds, from 18° to 20°, is not so great as that which Mr. Darwin observed in the beds of several craters of eruption in the Galapagos Islands, where the tuffs or mud-streams are inclined at angles of from 20° to 30°*.

We have four descriptions given us by eye-witnesses, of the origin of Monte Nuovo, and there is I think no real discrepancy between them. Two of these narratives, viz. those of Falconi and Pietro di Toledo, are cited by Sir William Hamilton; another is that of Francesco del Nero, recently published (1846) in the 'Neues Jahrbuch,' and translated in the Quarterly Journal of the Geological Society for 1847, while a fourth is that officially drawn up by the physician Porzio at the request of the Viceroy of Naples.

Francesco del Nero mentions the drying up of the sea near Puzzuoli, and how the soil where the present volcanic orifice exists sank down about forty feet in the morning, and then about midday began to rise up again, so that, where it had subsided four hours before, it was elevated into a hill from which fire issued, and where subsequently a great abyss was formed. Such was the violence, the noise and the glare of light, that this eye-witness who was in his garden was much terrified. Many stones and much earth were cast out by the subterranean fire, so that they accumulated round the opening in great quantity. He then describes the shape of the hill, and finishes by referring to Porzio. Pietro Giacomo di Toledo, after mentioning previous earthquakes and a slight general rise and drying up of the bed of the sea near the coast, says that at last, on the 29th Sept. 1838, the earth opened near Lake Avernus, and a horrid mouth was seen from which were vomited furiously and with a noise like thunder, fire, stones, and mud composed of ashes. Some of the stones were *larger than an ox*. The stones went as high as a cross-bow can carry, and then fell down, sometimes on the edge and sometimes into the mouth itself. The mud was of the colour of ashes and at first very liquid, then by degrees less so, and in such quantities that in less than twelve hours

* Volcanic Islands, p. 107.

with the help of the above-mentioned stones a mountain was raised. When on the third day the eruption had ceased for a time, people looked down into the crater and saw the stones boiling up in the middle. The day after, or fourth day, the crater began to throw up again, and on the seventh much more, and some persons were knocked down by the stones and killed.

Falconi's account also alludes to the earthquake and the bursting open of the earth, and how ashes and pumice-stones mixed with water were thrown up, and how the sea retired*. Porzio says, that a large tract of land between Monte Barbaro and the sea near Lake Avernus, was seen to raise itself and of a sudden to assume the form of a growing hill, and in the night this heap of earth (*terræ cumulus*), as if opening its mouth, vomited forth a quantity of fire, pumice-stones, and ashes.

On comparing all these contemporary statements, I infer that when the ground had first sunk down on the site of the future hill, the lava gradually propelled it upwards again, so that it was distended till it burst. The force of the escaping gases then hurled into the air large fragments of the soil, mixed with mud and pumice, part of which fell back into the boiling gulf, while a part fell over the edge of the crater and contributed to the building up of the cone. We can scarcely expect to find in the walls of such a crater, any considerable remains of the beds of tuff, which after subsiding and being again elevated must have been much shattered and torn to pieces by the elastic vapours and incandescent lava shot through them. All the descriptions would lead us to refer the great mass of the hill to the ejected mud and stones, accumulated in the course of a week by the intermittent volcanic action, and I can discover nothing implying such an upheaval of previously solidified and horizontal beds of tuff, as might lead us to expect that the walls of the crater would be found to consist of that more ancient formation. Von Buch indeed is said to have found some marine shells of existing Mediterranean species, like those which occur in the tuff of Campania, in some of the beds now exposed on the edges of the crater. Such shells may have been ejected in the mud mixed with sea-water which was cast out of the boiling gulf. If however they occur near the bottom of the funnel-shaped hollow, it is possible that some fragments of the original strata which were raised and burst through by the lava and gases may remain, or some of the huge fragments cast up into the air may well be discoverable in such a position.

Since writing the above I have received a memoir on the volcanic region of Campania by Signor Arcangelo Scacchi, published in the Memoirs of the Royal Academy of Naples for 1849, in which he entirely concurs with me in rejecting the theory of upheaval for Astroni, Monte Nuovo, and other cones of that district. The position of the trachyte of the Solfatara and of Astroni are shown to be different from what they would have been had the protrusion of the trachytic masses been the upheaving cause.

In regard to Monte Nuovo, Scacchi remarks, that Porzio's account

* Campi Phlegrei, pp. 70, 77.

upon the whole corroborates the doctrine of its having been formed by eruption, in proof of which the following passage is cited from Porzio's description of the event: "Verum quod omnem superat admirationem, mons circum eam voraginem ex pumicibus et cinere plusquam mille passuum altitudine unâ nocte congestus aspicitur." Signor Scacchi also adds, that the ancient temple of Apollo, which is now at the foot of Monte Nuovo, and the walls of which still retain their perfect perpendicularity, could not possibly have maintained that position had the cone of Monte Nuovo really been formed by upheaval.

Speaking of the fossil marine shells found in the tuff of Monte Nuovo, the same geologist observes, that as the tuff of the new volcano was formed in great part out of fragments of the ancient marine, shell-bearing tuff, the appearance of such fossils is easily explained.

In one part of the circuit of Astroni he alludes to beds of ejected materials which for a short space are inclined at an angle of 40°, and which he therefore imagines may have been partially dislocated, although the materials of the rest of the same cone remain in their original position. Here I may point to the fact mentioned by Mr. Dana in his account of the Sandwich Islands, that strata of ejected substances have sometimes an original inclination of 40° in the "cinder cones," although in the "tufa cones" formed near the sea, the slope of the beds does not exceed an angle of 30°.

Etna.

The great valley on the east side of Etna, called the Val del Bove, which forms a grand amphitheatre between four and five miles in diameter, is surrounded for more than three parts of its circuit by nearly vertical precipices which vary from 1000 to nearly 3000 feet in height. As this hollow is not in the centre but on the flanks of a great conical mountain, the precipices at the upper end of the valley are the loftiest, and they diminish gradually in height towards the lower side. The original form of the lower boundary of this enormous cavity is somewhat obscured by deluges of modern lava which have passed over it; but there can be scarcely a doubt, that were these removed, the nearly circular escarpment surrounding the vast cavity would be complete, although of slight elevation on the lower or eastern side where the lavas have poured over the edge of the rampart, seeming to have scaled it, just as they passed over the walls of Catania in 1669. There seems however to have been always one point, where there was a breach in the boundary cliffs of the Val del Bove. This was situated at the south-eastern end of the valley and is called the Valley of Calanna, a narrow ravine, on one side of which perpendicular precipices 400 and 500 feet high display a succession of volcanic strata intersected by a few dikes. The Valle di San Giacomo is the continuation of the Val di Calanna, and I conceive them to stand in the same relation to the Val del Bove, which the fossa grande probably held to the Atrio del Cavallo, or which the Baranco de las angustias holds to the caldera of Palma.

After my visit to Etna in 1828, I suggested that the Val del Bove may have been produced by engulfment, an opinion which M. de

Beaumont has adopted; and he has well remarked that it could not be attributed to explosions, for in that case vast showers of ejected matter comprising the former contents of the deep gulf or valley would have been apparent on the flanks of Etna. Without denying that some part of the missing rocks may be referable to engulfment, I am now disposed to suspect that their removal may have been chiefly due to the denuding action of the sea, which probably availed itself of a breach in some lateral crater, or perhaps some partial subsidence, to gain access to and scoop out a circular bay, and carry outwards in the course of ages the debris of the undermined rocks. On consulting my notes made in 1828, I find that this was my first impression on entering the great valley; but the extent of surface covered by modern lava-streams, under which the bottom of the Val del Bove, as well as the north side of the Val di Calanna are buried, conceals so much of the ground, as to render it difficult and somewhat dangerous to speculate on the origin of the vast hollow. I may however remark, in reference to aqueous action, that although no signs have been discovered of marine shells in any beds of fragmentary matter, composing the cliffs which bound the Val del Bove, yet marine organic remains have been traced to the height of 800 feet above the sea near Trezza. Nor can there be a reasonable doubt, that if the lower parts of the great mountain were not covered with modern lava and ashes, similar proofs of the former presence of the sea would be discoverable at much greater heights. We might indeed expect to find them at a higher elevation than any of the marine tertiary strata in Sicily, and these occur in the centre of the island as high as 3000 feet above the sea. If in the vicinity of Vesuvius beds containing marine shells of recent Mediterranean species have been upraised to heights of between 2000 and 3000 feet, we are prepared to suppose that the uplifting force may have been developed with equal, if not greater intensity on the site of Etna, although no sections can be obtained in consequence of the enormous outpourings of lava and showers of scoriæ by which the older portions of the mountain are masked.

The marine strata, containing shells of recent species, which crop out along the eastern and southern base of Etna, consist in great part of volcanic materials, of tuff, scoriæ, and ashes washed down into the sea, and of rolled pebbles of lava, as at La Motta near Catania, such as the destruction of the ancient denuded parts of a great cone may have furnished. The origin of some of these may have been contemporaneous with the excavation of the Val del Bove when the cliffs encircling that valley were washed by the waves of the sea.

In reference to the question of denudation, I may ask those who have visited and may revisit Etna to consider whether the rocks called Musarra and Capra, which appear to be outstanding masses of ancient lavas intersected by dikes, rising up near the middle of the Val del Bove, are not best explained by supposing them to be remnants of the once continuous cone not entirely carried away by the waves and currents; also, whether the ridges of very ancient and crystalline volcanic rocks called Rocca Giannicola and Rocca del Solfizio, which stand

out in relief from the cliffs at the head of the great valley, have not owed their preservation to their superior hardness, and consequent power of resisting aqueous action. There are in the tertiary limestones of the Val di Noto, in Sicily, circular valleys where the steep boundary cliffs have been shaped out into a great succession of ledges, separated by small cliffs, often producing an effect which I have compared (see 'Principles,' 1st edit. 1833, p. 110, vol. iii.) to the seats of a Roman amphitheatre. The precipitous rocks of white limestone thus carved out are sometimes 500 feet high. The period of this extensive denudation was very modern, geologically speaking, and we may infer that when the sea had power to shape out such cavities in rocks of uniform solidity and compactness, it may have exerted a far greater denuding energy on such alternations of stony and incoherent materials, as those now constituting the boundaries of the Val del Bove.

The dimensions of Etna are on a sufficient scale to have produced a large crater of denudation, had a cavity been excavated in the summit or centre, instead of on the flanks of the cone. Suppose the volcanic mass not to have been cut away to a greater distance from the axis of the mountain than the middle of the Val del Bove; there might have been a cavity formed three or four miles in diameter, encircled by escarpments from 3000 to 4000 feet in height. The dikes in that case would have been most numerous in the vicinity of the original and principal centre of eruption. At the nearest point to this centre now accessible is a rock already alluded to, called Giannicola, agreeing in mineral composition with the lavas of Etna, but highly crystalline, and massive, which Hoffmann describes as almost resembling granite in structure, and between 150 and 200 feet wide. The deeper, therefore, we are enabled to see into the composition of the volcano near its central axis of eruption, the more massive and crystalline are the contents of upfilled fissures.

I have offered in the 'Principles of Geology' an explanation of the fact on which M. de Beaumont has dwelt with much emphasis, that the more ancient parts of Etna have in the course of the last 2000 or 3000 years scarcely received any superficial accessions of lava and scoriæ (see 'Principles,' 7th edit. p. 398, 1847).

The dome-shaped or conical mass was probably several thousand feet less elevated when it was originally formed. After its bodily upheaval the eruptions would become more and more lateral and basal, or in other words, the exogenous growth of the cone would shift its chief place of development. Yet the focus of eruption continued in the loftiest part of the cone where the lava still rises to a great height, and often overflows, whenever lateral eruptions occur.

Mr. Hopkins has suggested, that if the denudation of the Wealden was anterior in great part to its elevation, the removal of an incumbent weight of matter from the central area might have enabled the expansive force to act with greater intensity on that space where so much less pressure remained to be overcome. In accordance with this view, we might expect that the Val del Bove, after the abstraction of volcanic masses varying in thickness from 500 to 4000 feet, would have become

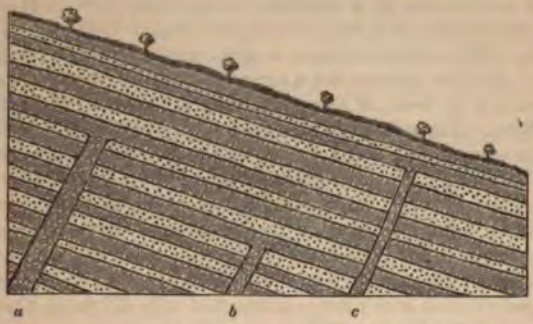
the almost exclusive theatre of eruptions. If such has not been the case, it is doubtless because the permanence of the site of habitual volcanic vents depends on deep-seated chasms and fissures in the earth's crust extending downwards many leagues, and which cannot be affected by changes of a comparatively superficial nature.

It is the opinion of M. de Beaumont, that the sheets of compact lava and alternating beds of scoriæ, which are now inclined in some of the cliffs encircling the Val del Bove at angles of 20° and 27°, were originally so horizontal that the lava emitted from different vents on the platform where they accumulated, flowed with equal freedom in every direction. To this circumstance he attributes the parallelism throughout a wide area, and the compact nature of a vast series of sheets of lava separated by more than 100 intercalated beds of pulverulent matter, cinders and angular fragments, such as are commonly cast out of craters during eruptions. The most cogent argument relied upon to compel us to embrace this view of original horizontality, is derived from the alleged fact that many of the dikes, intersecting the perpendicular cliffs alluded to, terminate upwards at different heights, and on reaching particular sheets of lava are there seen to blend, or "articulate" with them. The dikes are therefore imagined to have been feeders, or the channels by which the lava rose up from below.

The argument is ingeniously put in these terms. "Had the fluid matter been poured out on an inclined plane, the bed when consolidated would have formed an elbow with the dike like the upper bar of the letter F, instead of extending itself on both sides like that of a T (Mém. pour servir, vol. iv. p. 149), and, moreover, the series of sheets of lava would have been more numerous in parts of the mountain farthest from the axis, for all the dikes which were feeders or sources of lava would have poured their contents down the sloping cone and never upwards." Although the rectangular junctions here alluded to escaped my observation in 1828, and I have not revisited Etna since M. de Beaumont wrote his account of them, I shall take the liberty of offering a few comments on his statement of facts and method of interpreting them, as they appear to me so extraordinary that I feel at least entitled to demand, that the writer should acknowledge some difficulties in which his theory would involve us. In the first place I would ask, whence came the intercalated, incoherent and fragmentary beds? M. de Beaumont can hardly escape the inference, that they have been emitted from the same orifices as the dikes, if these last were really the feeders of sheets of lava flowing out into the atmosphere. But if the lapilli and scoriæ were cast out at the same points of eruption as the lavas, how could they possibly be of the same thickness near the vents and at a distance from them? If an even plain had existed at the commencement of these fissure eruptions, it would soon have acquired an irregular surface, for larger heaps of scoriæ would have been heaped up near the edges of the supposed linear vents, than at greater distances from them. I may also observe, that if vertical fissures gave vent originally at their upper extremities to horizontal sheets of lava so as to form dikes, joining at a right angle with the incumbent beds of lava, these dikes (fig. 10. *a*, *b*, *c*)

would be thrown as much out of the perpendicular as the beds they intersect, when the latter were tilted by subsequent movements. The dikes therefore which have been feeders ought to slope at angles of

Fig. 10.—*Volcanic Dikes.*



between 23° and 27° to the horizon, whereas in the drawing which I made of cliffs in the Val del Bove, I have represented them as nearly all perpendicular.

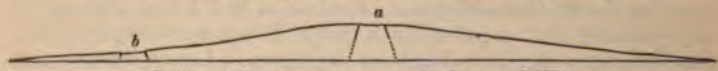
Had I seen a dike appearing to blend upwards with a sheet of lava, I should not have inferred any actual connection, unless I could have scaled the cliff, which is unfortunately inaccessible, and, hammer in hand, tested every inch of the junction. But had I thus assured myself of the fact, I should have first inquired whether the dike may not have sent off veins or branches which had penetrated between pre-existing parallel strata. If, however, I abandoned this idea as improbable because a sudden change of direction at right angles could scarcely occur or very rarely in such intrusive veins, I should have speculated on the possibility of such dikes having been filled partly from below and partly from above. After violent eruptions, the flanks of Etna have been fissured, and a bright light emitted from the rents has shown that there was incandescent lava below, although it has sometimes never reached the surface. It is conceivable, therefore, that lava-currents, descending from the higher and more central parts of the cone, might in their way fill up some rents of this kind, the tops of which are often left gaping after eruptions. Such a conjecture would at least relieve me from the extreme embarrassment in which I am placed by M. de Beaumont's hypothesis, for I am not called upon in that case to regard the dikes as the feeders of a series of uniform and parallel beds of lava, with their accompanying strata of intervening lapilli and scoriæ. The whole might then be imagined to have been poured out or projected from a permanent and powerful central vent, the eruptions being on a grand scale, so as to allow of a considerable degree of uniformity in the spreading of the materials over wide areas, on the sloping side of a great cone inclined at angles between 4 and 10 degrees. A steeper inclination may have been afterwards acquired during the distension and injection of the mountain mass.

We may naturally ask whether M. de Beaumont's notion of the existence of such linear vents as the dikes above alluded to, is borne out by the analogy of the phænomena of other active volcanos. Mr. Darwin tells me that in St. Jago he saw horizontal sections of the bases of small craters, and the mass of rock which had formed the source or feeder was of a circular, not a linear form. He has also given us the section of a cone of eruption in the Galapagos (Volcanic Islands, p. 109), where we have a most perfect natural dissection of a crater. In that case we see a series of inclined parallel beds of basalt, separated by beds of loose, fragmentary scoriæ, all parallel, and very uniform. Three of the sheets of lava unite with an irregular mass or column of the same substance, which was evidently the axis of the crater. The other streams of lava were no doubt, says Mr. Darwin, originally united to the same column, before it was worn down by the sea. Such a junction bears no resemblance to the dikes in the Val del Bove, because the lava has risen up a circular crater, and not by a linear fissure, and a cone has been formed; whereas it is precisely the absence of such small cones connected with dikes on Etna, which presents the difficulty to which I now allude.

Since the above remarks were written, I have perused Mr. Dana's valuable work, on the Geology of the United States' Exploring Expedition, published in 1849, and which reached London after this paper was drawn up. His observations on the great volcanos of the Sandwich Islands tend greatly to confirm my views, in regard to the formation of large flattened domes of volcanic matter poured out from a central vent, and they show that wide and extensive sheets of compact basalt and greystone have been formed on slopes considerably exceeding those which M. de Beaumont thought possible. In two of the principal volcanos of Owyhee, for example, Mounts Loa and Kea, we

Fig. 11.

Mount Loa, in the Sandwich Islands. (*Dana.*)



a. Crater at the summit. *b*. Crater of Kilanea.

have examples of huge flattened volcanic cones 15,000 feet high (see fig. 11), each equaling two and a half Etnas in their dimensions, from the summits of which, and from vents not far below the summit, successive streams of lava, two miles or more in width, and sometimes twenty-six miles long, have been evolved. They have been poured one after the other in every direction from the apex of the cone, down slopes varying on an average from 4° to 8°, but in some places considerably exceeding that inclination. Mr. Dana, indeed, convinced himself from actual observation, that, owing to the suddenness with which the lava cools, it may occasionally form on slopes equaling 25°, and still preserve considerable solidity; nay, it is even, he says, possible, from what he saw in the great lateral crater of Kilanea (fig. 11 *b*),

that a mass of such melted rock may consolidate on a slope of no less than 50° or even 60°, and be continuous for 300 or 400 feet. "Such masses are narrow," he adds, "but if the source had been more generous, it is not difficult to see that they would have acquired a greater breadth, and by a succession of ejections upon each cooled layer, even a considerable thickness might have been attained*."

The same author has also shown, that in the cinder-cones of the Sandwich Islands the strata have an original inclination of between 35° and 40°†, while in the tufa-cones formed near the sea, they have a slope of about 30°.

No one who reads the work alluded to will be of opinion, that the laws governing the formation and consolidation of sheets of basaltic or other kinds of lava have as yet been fully ascertained, or that the original inclination which they may have when flowing down the flanks of a volcanic mountain has been definitively determined by the eminent French geologist who has collected together so much valuable information on the subject.

There is another class of facts, however, brought to light by Mr. Dana's investigations, which bear directly on the rectangular junctions of dikes and streams of lava to which I have called attention in reference to the Val del Bove. He has shown, that, while copious streams of lava have been recently known to pour out from Mounts Loa and Kea from openings 13,000 feet above the level of the sea, there have been other contemporaneous fissures, produced at various elevations on the flanks of the same dome, out of which lava has streamed, unaccompanied by the ejection of any scoriæ. It appears that the lava is so liquid, that the entangled gases escape very freely from it, without casting up to great heights in the air liquid jets of the molten rock, to which volcanic dust and cinders owe their origin. Now as these rents are described as running in various directions, it is quite clear that currents of lava descending from higher points must, as often as they pass over them, give rise to junctions resembling those in the Val del Bove, though not strictly at right angles. Still it is quite necessary in the case of Etna, where we have to account for enormous masses of interpolated scoriæ, and where there has been so much viscidity in the lava, to derive the beds of fragmentary matter, as I before suggested, from a higher and more powerful and permanent central vent, for they could never have proceeded from the lateral openings or dikes without disturbing that uniformity and parallelism of the strata, on the existence of which M. de Beaumont has so emphatically insisted. It is not a little satisfactory to me to discover that Mr. Dana, with whose opinions I was previously unacquainted, has been led by his extensive examination of the volcanos of the Pacific Islands to reject Von Buch's theory of elevation-craters, although he has not alluded to the denuding action of the sea as affording an explanation of the large dimensions of many of the so-called cavities, such as Santorin, and the others on which I have dwelt in the preceding pages.

* Dana, Geol. of Amer. Explor. Exped. p. 359, note. † *Ibid.* p. 354.

Monts Dor and Cantal.

That the name of craters of elevation should have been given to large conical masses, in no part of which can any crater be discovered, whether of denudation, or engulfment, or eruption, is a singular instance of theoretical language, invented originally for distinct phænomena, becoming applied to another set of conditions, which are only in a small degree analogous. Although no craters are now discernible on the summits of Mont Dor and the Cantal in Central France, it is probable that they once possessed them, as I believe the greatest number of eruptions to have proceeded from the highest part of each mountain, where there is the greatest thickness of erupted lava and ejected matter. At this central point and around it, where so large a volume of basalt, trachyte, pumice, scoriæ, and other materials, whether solid or fragmentary, were emitted, the chief upheaval also may doubtless have occurred, and the slope of the conical mass may perhaps be greater now than it was originally. Yet as the average inclination of the dome-shaped mass of the Cantal is only 4°, and that of Mont Dor 8° 6′, we may reasonably question, after studying Mr. Dana's description of the recent additions made to the flanks of Mounts Loa and Kea, the one having a slope of 6° 30′, the other of 7° 46′, whether there is any real necessity for supposing, that the basaltic currents of the French volcanos were at first more horizontal than they are now.

The advocates of the elevation-crater theory, having assumed that the volcanic beds were in their origin almost horizontal, in Central France, found it indispensable to imagine, that a large cavity pre-existed in the granite, the lowest part of which coincided with what is now the highest part of the dome. At length, to use an expression of Ehrenberg in his paper on Volcanic Infusoria, "the concave beds were converted into a convex dome," and this as usual is referred to a paroxysmal effort of the subterranean force*.

This subject has been so ably discussed, in the controversy between MM. de Beaumont and Dufresnoy on the one side, and MM. Constant Prevost and Virlet on the other, that I need say no more on the subject. A closer observation of existing volcanos will decide whether the truth lies between the opinions of the opposite schools, and whether Messrs. Scrope, Constant Prevost, myself and others who have referred these mountains to successive eruptions proceeding chiefly from a central vent, have judged correctly, and how far we may have underrated the elevatory force, of which the intensity would no doubt be greatest at the point where the eruptive and injecting forces have been most energetic. That both the one and the other, however, have operated gradually, and with intermittent violence, not by any single great paroxysm, I feel as convinced as ever.

* Quart. Journ. Geol. Soc. vol. ii. p. 74, Memoirs.

JANUARY 9, 1850.

The following communications were read:—

1. *Observations on* DUDLEY TRILOBITES. By THOMAS WILLIAM FLETCHER, F.R.S., F.G.S., &c.

Genus LICHAS.

THE genus *Lichas* has received little attention from British palæontologists, and even Burmeister was compelled to omit any notice of it from the want of characteristic specimens. In the hope of being enabled to contribute some materials towards a more perfect knowledge of the genus, I am induced to offer to the Society a notice of several undescribed species which have recently been found in the Wenlock limestone of Dudley.

1. LICHAS BUCKLANDI, Milne-Edw., sp. PL. XXVII. figs. 1–5; and PL. XXVII. *bis*, figs. 1, 1 *a*, & 1 *b*.

SYNONYMS.—"*Trilobite de Dudley*," Al. Brongniart, 1822, Crust. Foss. pl. 4. f. 9.
Peltura Bucklandi, Milne-Edw. Crust. v. iii. 345. pl. 34. f. 12.
Arges Anglicus, Beyrich, Untersuch. über Tril. 2^te^ St. t. 1. f. 3.

This trilobite was first named by Prof. Milne-Edwards. Its cephalic shield is figured by Dr. Beyrich from a Dudley specimen. M. Brongniart, in his 'Histoire naturelle des Crustacés fossiles,' had previously given, under the name of "a Trilobite from Dudley," a figure of the under surface from a drawing by Mr. Stokes; merely remarking that the addition of spines to the tail, and the form of the cephalic shield, appeared to indicate a species differing from *Calymene Blumenbachii*.

The general form of the present species is oval and depressed; its length is about an inch and a quarter, and its width three-quarters of an inch; the length of the thorax exceeds that of the cephalic shield and tail, which are about equal, the axis or middle division being narrower than the lateral portions. Large tubercles cover the cephalic shield, which is less than a semicircle, and is deeply indented at the sides by the production of the front. The glabella is large, broad, widest below, and divided into five tumid lobes; the forehead lobe is linear, and separated by deep curved sulcations from the short, ovate, upper lateral lobes, which are of about equal width with it; these are smaller than the lower lateral lobes, which project considerably below them. No basal lobes are visible in this species. The neck lobe is prominent and broadest in the middle, and the neck furrow distinct. Eyes forward, small, and prominent, placed beneath the lateral indentation of the head, close to the lower lateral lobe of the glabella (PL. XXVII. *bis*, fig. 1 *b*). Front margin narrow, the part above the indentation being angular. Facial suture running immediately beneath the front margin, and curving downwards to the eye, parallel with the upper part of the glabella, below the eye curving outwards,

and terminating on the posterior margin. Eyelid tubercular, lentiferous surface smooth. Wings of moderate size, but not projecting forwards much beyond the eye; the posterior angles produced into rather short, broad spines. Hypostome almost equal in breadth to the upper part of the glabella above the lateral indentation, rounded at its insertion, and broadly truncate at its extremity. A strong concentric furrow separates the slightly convex anterior portion, which is deeply punctured, and a notch on each side divides it into two lobes, while sculptured lines with a few puncta occur only on the broad outer margin. The thorax has eleven rings, the axis is moderately convex, and not so wide as the glabella; it becomes gradually narrower towards its posterior part, and is divided by strong axal furrows from the pleuræ, which are semicylindrical; they are bent backwards at about a third of their length; the terminations of the pleuræ are separate, acute, and tubercular beneath. The tail is semi-oval with a spinous border; its axis convex, not quite equal in width to its lateral parts, and extending two-thirds of the entire length of the tail; a narrow ridge from its apex connects it with the raised border of the tail; on its upper part are two distinct rings, and one or two more indistinctly marked. The lateral lobes are flattened. Two narrow and sharply raised ribs arching outwards and ornamented with tubercles are placed on the anterior portion of each side, and produced into short spines extending beyond the raised margin of the caudal shield; five similar spines occurring on the margin below make up the entire number of nine spines, one of which is terminal. The interstices between the ribs, as well as every other part of the animal, are covered with large and small tubercles.

Variations.—One young specimen (fig. 3. Pl. XXVII.) has the margin immediately in front of the indentation with projecting angles almost produced into spines. The lower lateral lobes of fig. 1. Pl. XXVII. are narrower and less tumid than in most specimens, and the forehead lobe is wider in front than is usual.

2. L. HIRSUTUS, n. sp. PL. XXVII. figs. 6, 6 *a*, & 7; and PL. XXVII. *bis*, figs. 2 & 2 *a*.

The body rings (Pl. XXVII. *bis*, fig. 2) are much tuberculated, the axis tapering backwards, pleuræ bent backwards, and slightly downwards, the anterior ones at nearly half, and the posterior at about one-third of their length. Tail semi-oval, not including the six strong spines. Axis subconical, extending about two-thirds of the tail, its width about equal to that of the lateral portions, with one strong ring upon the anterior portion and transverse rows of tubercles indicating the position of three or four indistinct rings. A narrow ridge extends from the apex of the axis to the bifurcate extremity. Two lateral ribs on each side, arched slightly outwards and sharply raised, are produced into thick tubercular spines extending beyond the raised margin. Interstices roughly granular with large tubercles; small tubercles occurring between the large ones and appearing upon the spines of the border.

From the great similarity in the arrangement of the tubercles upon

the axis and sides, I am induced to regard Pl. XXVII. fig. 7, as the young of this species; the connecting ridge, however, is shorter in this specimen. The termination of the axis as represented in the figure is too obtuse.

The young specimen last mentioned exhibits the incurved margin; it is very convex and strongly marked with concentric lines, which also cross the spines. It has three lateral ribs on each side, but the middle rib probably represents the tubercular interstice of the older specimen.

3. L. Grayii, n. sp. Pl. XXVII. fig. 8; and Pl. XXVII. *bis*, figs. 3, 3 *a*, & 3 *b*.

The outline of the cephalic shield is nearly semicircular, but slightly gibbous in front, and the surface granular, but not coarsely tuberculated. Glabella very large and regularly convex, as broad in front as behind. Forehead lobe continuous from the narrow front margin to the neck lobe, and narrowing posteriorly, but expanding suddenly at the base, where it has a slight prominence on each side. Its anterior part is wider and more convex than the upper lateral lobes, which it overhangs. Upper lateral lobes pointed, but rather obtusely below, and not extending to the neck furrow. Lower lateral lobes triangular in form, and smaller than the upper; basal lobes small, narrow, elliptical, and placed widely apart; neck lobe broad, but not very prominent. All the furrows which divide the lobes of the head are shallow. Facial suture following the course of the anterior part of the glabella as far as the eye, its posterior course being unknown. Wing triangular and pointed, supporting the lunate eye upon a raised tubercular base; surface covered with tubercles of unequal size, and the incurved front edge strongly and concentrically striated (Pl. XXVII. *bis*, figs. 3, 3*a*, 3*b*). Eye moderate in size, and separated only by a slight furrow, not by any portion of the cheek, from the lower lateral lobe of the glabella.

I have named this new species after my friend Mr. John Gray, of Dudley, whose fine collection is well known to all admirers of Silurian fossils.

The head of this species has been figured in the 'Memoirs of the Geological Survey,' vol. ii. pt. 1. pl. 8, from a Malvern specimen, which was too imperfect to name.

4. L. Salteri, n. sp. Pl. XXVII. figs. 9 & 9 *a*; and Pl. XXVII. *bis*, fig. 4.

Glabella regularly convex, and broader in front than at the base; forehead lobe linear, more convex than the upper lateral lobes, about equal to them in width, not expanded below, but extending to the neck lobe. Upper lateral lobes ovate in form, and pointed in their lower portion; lower lateral lobes slightly tumid; cheeks (of which I find only a small portion supporting the eye) moderate in size, and separated from the glabella by a shallow groove. Eyes large and convex, the eyelid (rather exaggerated in fig. 9 *a*) nearly the size of

the lower lateral lobes; it is placed very forward, and quite apart from the glabella. Large and small tubercles cover the whole surface, some of the former appearing almost spinous. The larger tubercles are symmetrically disposed, about four pairs being placed at regular intervals along the forehead lobe.

This new species is named after my friend J. W. Salter, Esq., of the Geological Survey of Great Britain, in acknowledgement of his kind assistance in determining the species, and of much valuable information received from him.

5. L. Barrandii, n. sp. Pl. XXVII. fig. 10; and Pl. XXVII. *bis*, fig. 5.

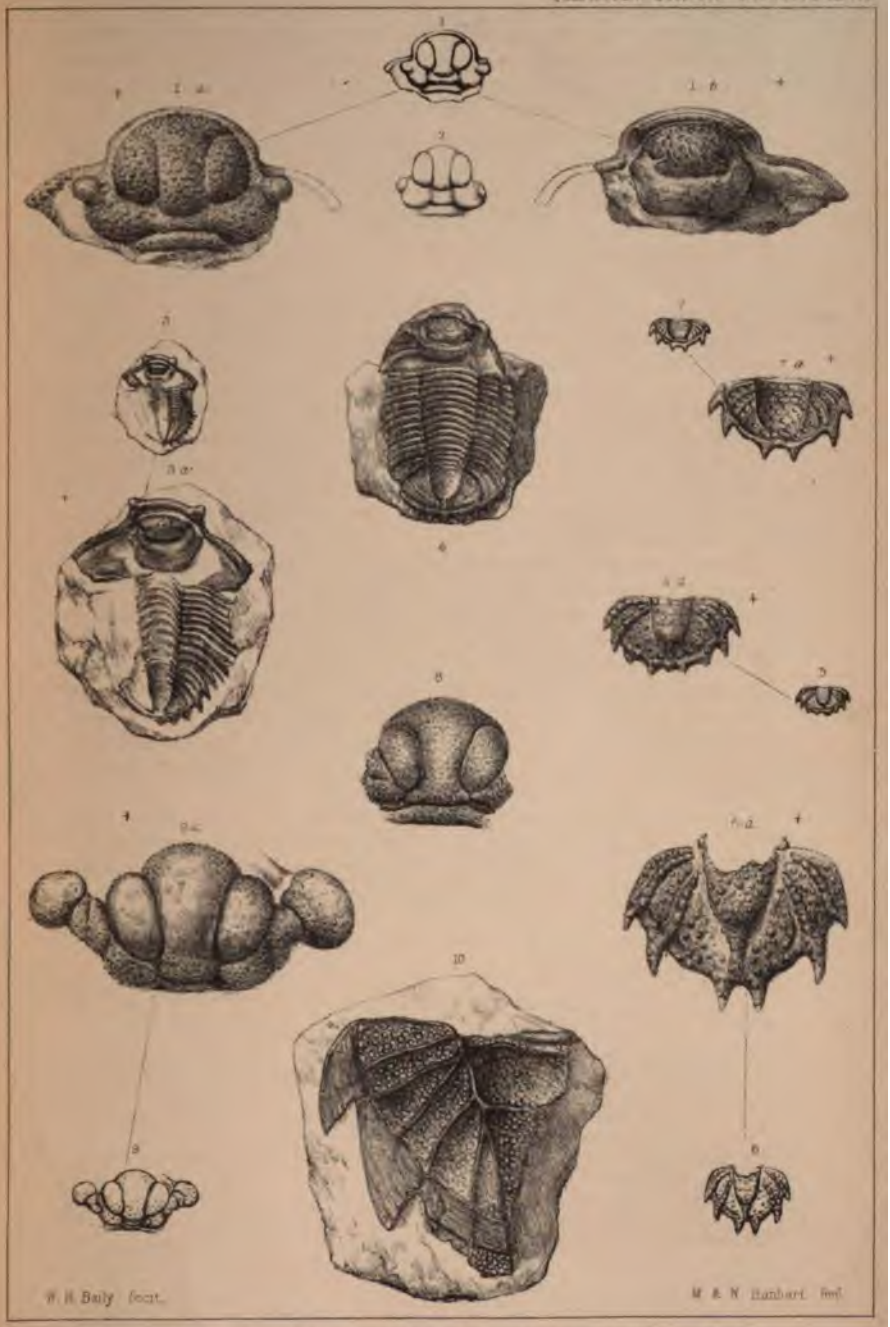
Strong tubercles of unequal size cover the whole surface of the tail, which is almost semicircular, its length being only two-thirds of its breadth; the axis is wider than either of the side lobes,—it is subconical, and moderately convex in its upper part for rather more than half the length of the tail, then contracted suddenly to less than half its former width, but does not taper to a point; it is depressed in its lower portion, so as to subside into the general surface of the tail considerably in advance of the bifurcate apex. The upper part of the axis is divided into three distinct rings, followed by a broad central tubercle. Each of the flattened sides of the tail consists of three foliaceous pleuræ or lobes terminating in broad projecting teeth, and separated from each other by narrow sharp furrows; each lobe is marked obliquely along its middle by a groove; the two upper lobes are directed outwards, their tips, projecting and acute, are recurved; the third or posterior lobe is directed entirely backwards, and even inwards, to meet the corresponding lobe of the opposite side, from which it is separated by the broad terminal notch. The pleural grooves of the two upper lobes extend nearly to the tips, but run only a short distance in the posterior lobes. The incurved under portion is concentrically striated.

This remarkable species has been named after my friend and correspondent M. Barrande, of Prague, whose forthcoming work on the 'Système Silurien du centre de la Bohème' will doubtlessly enhance a reputation already well established.

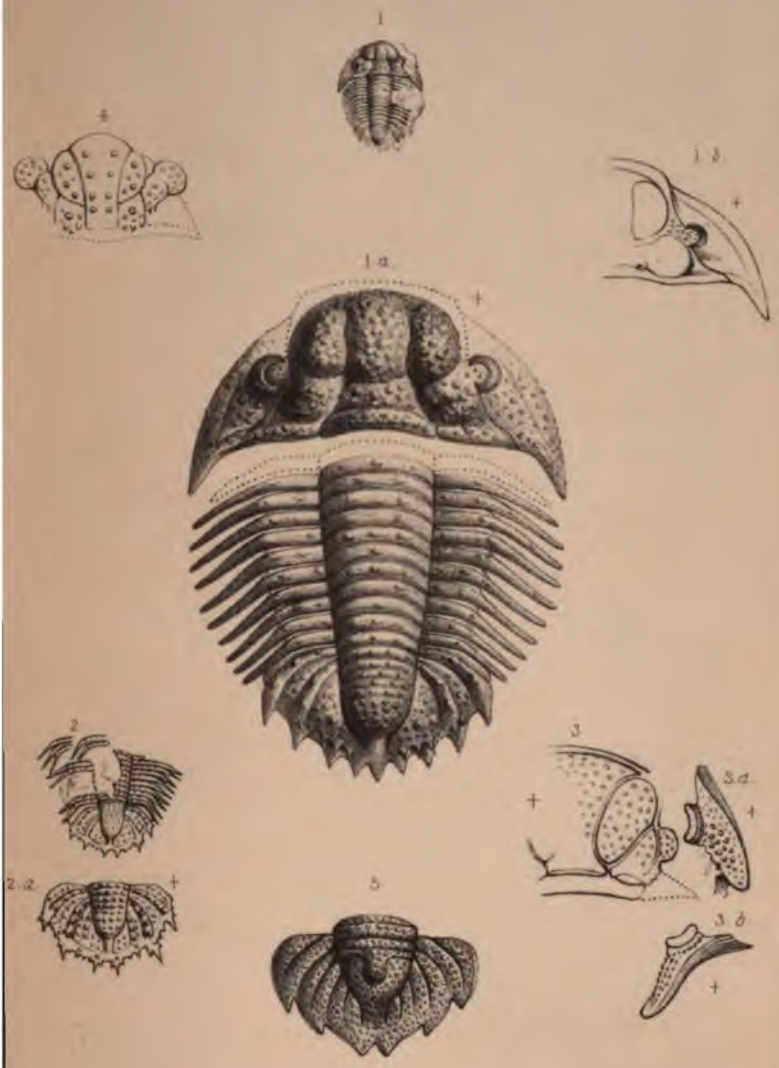
L. Bucklandi is of more frequent occurrence than the other species, which are rare.

EXPLANATION OF PLATE XXVII.

Fig. 1. *Lichas Bucklandi*; a small specimen differing slightly from the usual form.
Fig. 1 *a*. Ditto, upper side, magnified.
Fig. 1 *b*. Ditto, lower side, magnified.
Fig. 2. The same species, of the ordinary form.
Fig. 3. Lower side of a young specimen, with the front of the head very angular.
Fig. 3 *a*. Ditto, magnified.
Fig. 4. Lower side of a full-grown specimen.
Fig. 5. Tail of a young individual.
Fig. 5 *a*. Ditto, magnified.



Figs 1-5 Lichas Bucklandi, M Edw. Fig. 6, 7. L. laxatus, Fletcher. Fig. 8 L. Grayii, Fletcher.
Fig. 9. L. Salteri, Fletch. Fig. 10. L. Barrandi, Fletch. The figures marked + are magnified 2½ times.



R. Bone
M.A.N. Hanhart Imp.

Fig 1. *Lichas Bucklandi*. – Fig. 2. – *L. hirsutus*. – Fig. 3. *L. Gravyii*. – Fig. 4. *L. Saltert*. – Fig 5. *L. Barrandii*. – The figures marked + are magnified.

Fig. 6. *L. hirsutus.*
Fig. 6 *a*. Ditto, magnified.
Fig. 7. Young specimen of *L. hirsutus*?
Fig. 7 *a*. Ditto, magnified.
Fig. 8. *L. Grayii.*
Fig. 9. *L. Salteri.*
Fig. 9 *a*. Ditto, magnified: the eyelid on the right side is exaggerated in size.
Fig. 10. *L. Barrandii*: under surface of the tail, showing the incurved striated margin.

Figs. 1, 4, 5, & 8 are from specimens in the cabinet of Mr. John Gray, to whose kindness I am indebted for the loan of them; the remainder are from my own collection.

EXPLANATION OF PLATE XXVII. *bis.*

Fig. 1. *Lichas Bucklandi.* A nearly perfect specimen; the first thorax-joint is lost,—its position is indicated in 1 *a* by dots.
Fig. 1 *a*. A highly magnified view of the same.
Fig. 1 *b*. Outline, showing the eye and facial suture.
Fig. 2. *L. hirsutus*; showing ten of the body rings and the tail.
Fig. 2 *a*. The tail magnified.
Fig. 3. *L. Grayii*; one side of the glabella, with the lateral and basal lobes; the course of the facial suture posteriorly is indicated by dots.
Fig. 3 *a*. The same; the wing, with the eye.
Fig. 3 *b*. Ditto, viewed from the front.
Fig. 4. *L. Salteri*; a good specimen, showing the regular arrangement of the tubercles on the head.
Fig. 5. *L. Barrandii*; a perfect tail.

Figs. 1 *b*, 3, & 4 are from Mr. Gray's collection; the rest are from my own.

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2. *On certain Beds in the* Inferior Oolite, *near* Cheltenham. By the Rev. P. B. Brodie, M.A., F.G.S. *With Notes on a Section of* Leckhampton Hill. By H. E. Strickland, Esq., M.A., F.G.S.

The inferior oolite in the immediate neighbourhood of Cheltenham, has been already well described in the "Geology of Cheltenham," by Sir R. Murchison, Mr. Buckman, and Mr. H. E. Strickland; but as there is a very interesting bed called "the roestone" by local geologists, which, however, for obvious reasons it will be better to name "*shelly freestone*," containing several new and peculiar fossils, many of which have not been previously noticed, it may be desirable to lay a brief account of it before the Society.

The outer escarpments of the Cotswold Hills are composed of the inferior oolite and lias, and form an important feature in the geology of the county, presenting bold headlands along the vales of Gloucester and Berkeley, in some instances rising to the height of more than 1000 feet above the level of the sea, and extending in a tortuous line for several miles from north-east to south-west. They constitute the eastern boundary of the Severn; the towns of Cheltenham and Gloucester lying in bays at the foot of this range of hills, the base of which consists of lias, surmounted by a variable thickness of oolite.

The following divisions (see Section, p. 242) of the oolitic strata at Leckhampton Hill, near Cheltenham, where the shelly freestone may be most advantageously studied, have been principally proposed and adopted by the authors of the work above referred to; although later investigations by Mr. Strickland prove, that their relative thickness is greater than has been generally supposed, and I have therefore followed his admeasurements. The summit of the hill is capped by a rough, gritty stone, loaded with casts of *Trigonia costata* and *T. clavellata*; but neither this, nor the thin and very fossiliferous band of clay which separates it from the "Gryphite grit," are well developed in this section. Hence the latter (No. 2 of Section, p. 242) may here be more correctly said to be the first stratum in descending order. It is a coarse calcareous grit, full of the *Gryphæa cymbium* and numerous other shells, the former of which is characteristic. The oolite marl*, or cream-coloured marly oolite, which succeeds (No. 5 of Section, p. 242), is in places hard and concretionary, but often friable, and breaks up irregularly by the action of frost: it may be estimated at seventeen feet in thickness. It contains a large species of *Natica*, *Plagiostoma*, *Arca*, *Rostellaria*, and *Terebratula fimbria*; the last, which occurs in profusion, marks and is confined to this bed. It is locally rich in corals, one species occurring in large blocks exceeding two feet in length, and generally speaking, like the Pisolite, must have formed a coral-reef in the ancient ocean. It has also been subject to much denudation, not only when it first emerged from the waves, but probably at a later period; for the corals and shells are frequently water-worn, and many of the former enter largely into the composition of the oolitic gravel which fills up hollows in the lias plain beneath. Towards the south this marl is not so readily traced, until it appears again at Crickley and Birdlip, the top of the hill being composed of the great and more important underlying mass, which forms the thickest division of the inferior oolite, upwards of a hundred feet thick, and which is used for building and other purposes. It is ordinarily termed "freestone" (No. 6 of Section), and in part forms a fine-grained, light-coloured oolite, closely resembling the Bath freestone, and is nowhere absolutely destitute of organic remains, the harder stone being made up of comminuted fragments of shells and corals. The more perfect specimens are almost entirely confined to two or more shelly masses, one of which may be seen at the summit of the hill on the south, where it crops out, and has been broken up and water-worn. There it becomes flaggy, and bears a striking mineralogical resemblance to certain beds in the Forest marble and Great oolite, and this is the prevailing character of these subordinate groups. One of these upper shelly layers may be traced from

* The oolite marl reappears near Stroud, and, with very slight lithological variations, is similar to that at Leckhampton. It affords, like the latter, many shells peculiar to it, but they are more numerous and better preserved. Mr. Lycett's fine collection contains several species which have not yet been observed in the vicinity of Cheltenham. Viewed as a whole, the shells are remarkably distinct from all other beds in the great and inferior oolite. Mr. Lycett possesses more than 130 species from this stratum.

north to south along the whole of the escarpment, and at one spot near the Devil's Chimney, where the freestone is thickest, it shows itself about eighteen feet below the oolite marl, and is there a coarse crystalline rock, mainly composed of shells and corals, a foot and a half thick. The more interesting fossiliferous division of the freestone immediately overlies the Pisolite ("Pea-grit" of Murchison*), and attains a thickness of seventy-five feet. It is a coarser and softer oolite than the upper part of the freestone, of a yellowish-white colour, and abounding in a great variety of small shells and corals, many of which belong to new species, and which are strikingly contrasted with those in the superior and inferior beds. Since the freestone is traversed at irregular intervals by certain shelly layers, containing the same characteristic fossils, and the whole evidently forms one connected stratum, which has been exposed, apparently, to currents of water of greater or less intensity, and the shells and corals in consequence more or less abraded, it will be better to adopt the term "shelly freestone†," instead of "roestone," which simply means oolite.

As the Pisolite can be followed all along the line of the escarpment, the lower shelly beds in the freestone can be accurately defined; but the upper fossiliferous strata, from the height of the cliff, are more difficult to distinguish. They may be best examined on the western brow of Leckhampton Hill, where the oolite marl above, and the Pisolite below, form very good horizons for marking the course of the intervening freestone. On the north and south the freestone is much reduced in thickness, and at the more southern end of the hill the higher beds are not exposed; but at the northern extremity, opposite Cheltenham, the upper series is largely developed. The general and true dip is at an angle of about seven degrees to the south-east. The freestone and associated deposits extend for several miles along the entire line of the Cotswolds, in the district now under review, where they present occasional lithological variations, but are in most cases equally rich in organic remains. On the whole, Leckhampton Hill affords a good type of the lower oolitic system constituting the outer edge of the Cotswold chain in its range from north-east to south-west across Gloucestershire, although there are, as may be expected, certain local distinctions in the comparative thickness, mineralogical structure, and zoological contents of particular beds. The superior strata, however, above the Trigonia grit, are not exposed at Leckhampton, but occupy the higher grounds on the east, up to their junction with the Stonesfield slate.

With the permission of my friend Mr. Strickland, I subjoin the following corrected section of Leckhampton Hill, from the Trigonia grit to the lias inclusive.

* Geology of Cheltenham, 1834, p. 12. sections figs. 1 & 2.

† The term "*shelly freestone*" must be understood to apply to the lowest and more fossiliferous division of the freestone just above the Pisolite, and to the other shelly bands which are interspersed amongst it. The word "freestone" has been already given by Sir R. Murchison to the upper part, and may therefore be used in contradistinction to the above, though in common parlance it may with propriety designate the entire sequence between the oolite marl and the Pisolite.

Section of Leckhampton Hill, on the scale of 180 *feet* = $\frac{1}{8}$ *inch.*

	feet.	in.	
1. Trigonia grit	7	6	Inf. Oolite, 230 ft.
2. Gryphite grit	7	0	
3. Rubbly oolite, with many fossils	24	0	
4. Fragmentary oolitic freestone, apparently unfossiliferous	26	0	
5. Oolite marl with *Terebratula fimbria*	17	0	
6. Freestone, quarried for building, with shelly layers at irregular intervals, the thickest and more fossiliferous portions at the base	106	6	
7. Pisolite ("Pea-grit") and ferruginous oolite ("Belemnite bed") and sand*	42	0	
8. Upper lias, about	180	0	Lias, 749 ft.
9. Marlstone, about	50	0	
10. Lower lias (probably 600 feet thick)	519	0	
Total height above the sea	978	0	

From the above it will be observed, that the lias forms the main portion of the outer escarpments of the Cotswolds, being nearly 750 feet thick, while beds resting upon it, and probably forming nearly the entire series of the inferior oolite, do not amount to more than 230 feet.

In tracing the course of the inferior oolite on the south and south-west, the lower beds will be found to undergo considerable changes of mineral structure, and occasionally in fossil contents. Thus at Painswick Hill near Gloucester, the lowest stratum seen on the north-western face resembles a similar band at Frocester, about to be described, and contains a variety of fossils. Ascending the hill on the north-east, the Trigonia and Gryphite grits are well-defined, and abound in fossils, among which *Gryphæa cymbium*, *Lima proboscidea*, *Pecten*, *Gervillia*, &c. are most frequent. The Trigonia grit is much thicker than at Leckhampton, although in both localities it is a close-grained, hard, shelly stone, of a light-brown colour, loaded with a large species of *Cucullæa*, *Gervillia*, *Modiola*, *Pecten*, and other shells. Towards the town of Painswick the "freestone" is extensively quarried for several economical purposes, and altogether approximates closely in character to its equivalent at Leckhampton, though there seem to be fewer shelly layers, and these much less rich in the remains of molluscous animals. Passing on in a more southerly direction, to Selsley Hill, close to Stroud, a remarkable variation takes place in some of the members of the inferior oolite, the

* I hope in a future communication to give a more detailed account of the beds below the freestone, the lowest of which, as they approach the lias, present some new and interesting characters.

lowest of which exposed are composed of freestone with irregular shelly bands as at Leckhampton: but I could not positively decide whether there was here or at Painswick a thickness of forty feet of rock containing shells, more or less perfect, at the base of the freestone, which is a distinctive feature in the Leckhampton section (p. 242). This is overlaid by the oolite marl with many *Nerinææ* and other shells, somewhat reduced in bulk, which, in its turn, is succeeded by a flaggy, bastard freestone, identical with No. 4 of the Section, p. 242, near Cheltenham. The above constitute the lower quarries; the Pisolite (if present) and lias are not visible, the sides of the hill being covered with grass. The upper quarries consist of a coarse kind of freestone, about fifty feet thick, clearly representing the series at Leckhampton which intervene between the bastard freestone (No. 4) and the Trigonia grit (No. 1). It is a shelly, calcareous, marly oolite, though more sandy above, where it is traversed by thin layers of carbonized vegetable matter, and yields many small *Cidares* with attached spines and teeth, stems of *Pentacrinites*, *Terebratula*, and a species of *Pollicipes*, apparently the same as the "*P. ooliticus*" from the Stonesfield slate. A thin, flaggy, oolitic rag forms the top of the quarry, the superior strata being concealed until near the summit of the hill, which is capped by the Trigonia grit, harder and more crystalline than its equivalent near Cheltenham, which is its prevailing character in this neighbourhood. It contains *Arca*, *Myacites*, *Trigonia costata*, *Avicula*, and *Trichites*, one of the thick fibrous shells allied to *Perna* and *Inoceramus*. The Gryphite grit and rubbly oolite are most likely wanting, and their place is occupied by the strata above described. I was unable to determine the relative thickness of the inferior oolite in detail, either here or at Painswick; but on the whole, the oolite marl and freestone are thinner than at Leckhampton. I am informed by Mr. Lycett, that the shelly freestone has its representative in one or two places at least in this part of Gloucestershire, being far beneath the building-stone, and immediately above the lower rag (Ammonite and Belemnite bed), which, near Cheltenham, is represented by the ferruginous oolitic stone below the Pisolite, containing many Belemnites (No. 7 of Section). The sands and sandy marls beneath, often passing insensibly* into the lias, may be seen at Leckhampton and Crickley occupying a similar position, and reposing immediately upon the subjacent lias. The beds above the lower rag vary very much, being hardly alike in any two places, sometimes occurring as shelly freestone, or barren bastard freestone, more or less fossiliferous. The upper stratum on Frocester Hill, a few miles south-west of Stroud, and eleven south of Gloucester, is composed of fine-grained oolite with few fossils, the chief of which are corals, and these not abundant. It evidently occupies the position of the Cheltenham freestone, though differing to a certain extent. The more shelly portions seem to be absent, or at any rate deficient in those peculiar and remarkable characteristics observable at Leckhampton. On the north-eastern escarp-

* This must be an exception to the general rule, for in most other instances in the Cotswolds, the transition from the oolite to the lias is abrupt and decided.

ments this band is considerably thicker, but much diminished on the opposite side. Towards Coaley it passes into a soft, gritty, ferruginous oolite, full of comminuted shells and small corals, cemented together by a sort of calcareous paste, the outer surface of which is covered with broken joints of a new species of *Pentacrinites*, long stems and fragments of the head being sometimes obtained. This bed is of no great thickness, and most nearly resembles one at Crickley, between Cheltenham and Birdlip. The lower strata are very fossiliferous, and belong to the lowest division of the inferior oolite, and may be traced at Painswick, Crickley, Leckhampton and Cleeve Hills, the clays of the upper lias appearing in contact immediately beneath. They for the most part consist of a coarse ferruginous oolite, made up of reddish-brown, oval grains. *Ammonites*, *Nautili*, and *Belemnites**, nowhere very abundant in the north-eastern division of the Cotswolds, occur here in profusion, with various other shells. Lithologically, these beds are identical with the celebrated beds at Dundry and other places in Somersetshire. They thence run south to near Wotton-under-edge, where they are characterized by an equal number of Cephalopoda. The upper part of Stinchcomb Hill intervening is composed of a compact oolite, like the thickest bed at Frocester, very barren in organic remains, with the exception of *Terebratula spinosa*, specimens of which are numerous and well-preserved: and if, according to Mr. Lycett, this species is limited to the top of the inferior oolite, this stratum must be superior to any of the others referred to in this paper. The rest of the oolitic range north-east of Cheltenham has the same general structure as the formation at Leckhampton, though the highest hills, such as Cleeve, are capped by superior strata. The richest fossiliferous beds in the inferior oolite of the whole of the above district are, the clay dividing the Trigonia grit from the Gryphite grit, seen at Cold Comfort, the Gryphite grit, the shelly freestone, and the lowest strata on Frocester Hill. It remains to be proved whether the shelly freestone occurs in the inferior oolite elsewhere; but in those parts of Wilts, Dorset, and Somerset, where I have had opportunities of examining it, I have not noticed any bed of a similar nature. It is interesting to observe the strong lithological resemblance which the "shelly freestone" bears to the great oolite, especially at Minchinhampton; but the most important fact is, the identification of a large number of the shells with certain species which abound at that spot. Most of these are of small size, and very rarely have both valves attached: the Conchifera are most abundant, while the Gasteropoda are less numerous, and generally very minute, though a large species of *Patella* (*P. rugosa*) is sometimes met with. Some retain their original colour, such as *Arca*, *Donax*, *Mytilus*, and *Trigonia*. A large proportion are much water-worn, the shelly portions of the freestone being literally made up of comminuted fragments of shells, among which the more perfect specimens are widely dispersed.

* Belemnites are plentiful at Leckhampton in the stratum *immediately* below the Pisolite, which evidently forms a diminished representative of the inferior beds at Coaley, &c.

The most predominating genera are, *Arca*, *Avicula*, *Gervillia*, *Lima*, *Ostrea*, *Pecten*, and a new smooth species of *Patella*, common also to the great oolite. The almost entire absence of the *Cephalopoda* is remarkable, a small Ammonite and an imperfect Belemnite being all at present known from this part of the inferior oolite; and it is a curious coincidence, that Mr. Lycett remarks the extreme rarity of that class in the shelly beds of the great oolite. Besides Testacea, there are many fragments of *Pentacrinites*, joints of *Asterias*, one species of *Comatula* or *Eugeniacrinus*, a few small claws of *Crustacea*, and teeth of Sharks, which are very scarce; but no traces of the drift-wood or rolled pebbles, so frequent at Minchinhampton. There are also a variety of small corals, more or less abraded. Mr. Gomonde's cabinet and my own contain upwards of one hundred and sixty species of shells from the shelly freestone alone, many of which are peculiar to the inferior oolite, and range indiscriminately through all the beds; some being confined to the shelly freestone, and a still larger number identical with species which prevail in the great oolite. In a series forwarded to Mr. Lycett, he identified *fifty-two* out of *one hundred and fifty-two* species, previously recognised only in the superior formation, and he was surprised to observe the proportion so considerable. Mr. Morris had before noticed sixteen out of twenty-six species in a choice collection first obtained by Mr. Gomonde from Leckhampton Hill. My late lamented friend Mr. Pearce was so struck with the lithological and zoological resemblance of these subordinate divisions of the freestone to the great oolite, that at first he could scarcely believe the specimens in question were really obtained from the inferior oolite. These facts certainly form an interesting and novel feature in the history of this deposit, and from them we may infer that the shelly freestone, though of older date than certain beds in the great oolite at Minchinhampton, which it so closely resembles, was deposited under very similar conditions, and the sea, to which it owed its origin, still inhabited by many species of mollusks, which previously flourished at a much earlier period*. It would seem probable that this stratum was accumulated in a shallow sea, at no very great distance from the shore, where strong currents prevailed†, which accounts for the imperfect and abraded state of the majority of the fossils. This statement is in a measure confirmed by some remarks with which Professor Forbes has been kind enough to favour me. He states, that "the assemblage of testacea, and the conditions under which it occurred, seemed to him to indicate a depth of somewhere about fifteen fathoms, in a sea vexed by currents. With respect to the valves of the shells being disunited, this may happen at any distance from land, for in dredging forty or more miles from the coast in the British seas, provided the bottom is con-

* It should be remarked, that the fossils in the great oolite at Minchinhampton are usually much larger, as well as more varied and abundant. Ample details are given, and a copious catalogue of species, in Mr. Lycett's valuable paper in the Quart. Journ. Geol. Soc. vol. iv. p. 181.

† This agrees exactly with Mr. Lycett's opinion respecting the origin of the shelly beds of the great oolite.

tinuously within the limits of the coralline zone, the same fauna might be found as that close to the shore; consequently any inference of neighbouring land, where no very precise facts indicating its proximity are present, must be drawn within considerable limits."

These observations also tend to connect the upper and lower oolites more intimately together; and it is not unlikely that future investigations will corroborate this opinion. It is well known, that many genera and species, which had been long considered to be limited to particular groups of strata, are now found to have a far wider range*, and it may be ultimately necessary, in accordance with this, to remove or modify certain divisions or subdivisions, as being in some measure arbitrary and conjectural.

The inferior oolite and lias exercise an important influence on the physical geography of Gloucestershire; the wearing away of the shales in the latter has effected a gradual descent to the wide plain below, and the whole of the Cotswold range commands fine views over the adjacent valley. This extensive vale is limited by many natural boundaries, not only where the Cotswold escarpments form an unbroken line of bold promontories, but by the distant syenitic axis of the Malverns on the north-west, the May Hill anticlinal, and the further prolongation of the Silurian system at Huntley and Longhope on the west. And we are thus forcibly reminded of that comparatively recent epoch, when the estuary of the Severn extended to the base of these hills, of which we have at least one decisive proof in the occurrence of several *marine* plants still living in the neighbourhood†, although it is singular that it has left few other traces of its former existence. In other places the inferior oolite has been subjected to local disturbances and dislocations, and consequently is divided into numerous transverse gorges, which present some of the most picturesque scenery in the county, especially near Stroud, Woodchester, and Rodborough, where the hills are well-wooded, and diversified by rugged declivities and gentle undulations.

The following list of shells from the freestone is of course at present very incomplete; and as there is a great deal yet to be done in the oolites of Gloucestershire, especially by a comparison of the shells in the upper and lower divisions, I wish it to be clearly understood, that the above remarks and accompanying table of fossils, although founded upon recent discoveries, are only so far conditional, and may require considerable additions and alterations when further researches have been made. A few have been named by Mr. Morris, but the identification of the greater number rests upon the authority of Mr. Lycett, to whom I am indebted for this important service. My

* Thus in the lower strata of the inferior oolite near Ilminster, I detected the same species of *Spirifer*, so frequent in the marlstone below, whilst the upper lias contains a few species hitherto supposed to be peculiar to the inferior oolite. The upper lias of that district also affords two species of *Leptæna*. At Bath, again, the *Avicula inæquivalvis* is common to the inferior oolite and marlstone (Lyell's Elements, 2nd ed. vol. ii. p. 59), and many other examples of the same sort might be cited.

† Professor Buckman has lately published an interesting pamphlet upon this subject, entitled, "The Ancient Straits of Malvern."

friend Professor Buckman has also revised the list, and his previous acquaintance with the formation under review gives additional confirmation to these details.

My friend Mr. Gomonde, of Cheltenham, however, was the first to investigate the organic remains of the freestone at any length, and to point out the number of species, which his fine local collection amply illustrates. He has also added some new species from other beds, especially the rubbly oolite (No. 3 of the Section, p. 242), and Pisolite, which had not been previously brought to light in Gloucestershire. Indeed, I have to thank him for much information and assistance in my examination of this member of the lower oolite.

The freestone is succeeded by the Pisolite ("Pea-grit" of Murchison), and ferruginous oolite (*Belemnite bed*) and sand (No. 7 of Section); the former so called from its peculiar structure, being composed of large oval grains, of a yellow colour, cemented by calcareous matter, the whole not exceeding forty-two feet thick. It contains several shells and minute corals. At Crickley and Cleeve the Pisolite is much thicker than at Leckhampton, and the ferruginous oolite may be occasionally observed beneath. This latter rests conformably on the clays of the upper lias, which it is not within the province of this paper to describe.

Table of Organic Remains from the "Shelly Freestone" (properly so called) of the Inferior Oolite, compared with similar species in the Great Oolite.

[Those found also in the Great Oolite are marked thus *.]

ZOOPHYTA.

Astræa.
Caryophyllia.
Fungia, and other Corals.

ECHINODERMATA.

*Acrosalenia Hoffmanni (Cidaris), *Roem.*
*Cidaris subangularis, *Goldf.*
*—— coronata, *Goldf.*
——, species undetermined.
Cidarites crenularis, *Lamk.*
——, species undetermined.
Asterias (joints of).
Eugeniacrinus?
Pentacrinus, n. s.

ANNELIDA.

Serpula socialis, *Goldf.*
——, n. s.

CRUSTACEA.

Astacus (claws of).

CONCHIFERA.

Arca lata, *Dunker.*
*—— pulchra, *Sow.*
—— trisulcata, *Münst.*
Astarte depressa, *Münst.* (sulcato-striata, *Roem.*)
*—— orbicularis, *Sow.*
——, n. s.
Avicula complicata, *Buckman.*
*—— ovata, *Sow.*
Cardium cognatum, *Phill.*
——, three other species.
Cucullæa cucullata (Arca), *Münst.*
—— elongata, *Sow.*
—— funiculosa? (Arca), *Münst.*
—— oblonga, *Phill.*
——, four new species.
*Corbula curtansata, *Phill.*
*—— involuta, *Münst.* (striata, *Buckm.*)
—— depressa, *Phill.*
——, n. s.
*Cypricardia cordiformis, *Desh.*
Corbis, n. s.
Cytherea, n. s.
Donax? two new species.
*Gervillia costatula, *Deslong.*
—— tortuosa (Gastrochæna), *Phill.*
—— lata, *Phill.*
——, two new species.
Hiatella, n. s.
*Hinnites velatus (Spondylus), *Goldf.*

Hinnites comptus (Spondylus), *Goldf.*
*Lima duplicata, *Sow.*
*—— lunularis, *Desh.*
*—— læviuscula, *Goldf.*
*—— ovalis (Plagiostoma), *Sow.*
*—— punctata, *Desh.*
*——, three new species.
*Lucina despecta, *Phill.*
*Mactromya globosa, *Agass.*
*Myoconcha crassa, *Sow.*
Mytilus cuneatus, *Phill.* (Modiola, *Sow.*)
*—— pectinatus, *Sow.*
*—— pulcher, *Goldf.*
—— striatulus, *Münst.*
*——, two new species.
*Nucula variabilis, *Sow.*
*Ostrea costata, *Sow.*
*Opis lunulatus (Cardita), *Sow.*
——, n. s.
Panopæa? n. s.
*Placuna armata (Plicatula), *Goldf.*
*—— Jurensis, *Roem.*
——, n. s.
*Pecten clathratus, *Roem.*
*—— lens, *Sow.*
—— vimineus, *Sow.*
——, two new species.
*Perna mytiloides, *Lamk.*
Psammobia lævigata, *Phill.*
*Sphæra Madridi (Cardium), *Archiac.*
(Cardium incertum, *Phill.*)
Terebratula plicata, *Buckman.*
—— simplex, *Buckman.*
*——, six new species.
Trigonia clavellata, *Sow.*
*—— costata, *Sow.*
——, three new species.
*Venus suevica, *Münst.*
*—— trapeziformis, *Roem.*
——, n. s.

GASTEROPODA.

Ceritella (n. g. Lycett), two new sp.
Cerithium, ten new species.
Cylindrites (Acteon), two new sp.
Delphinula funata, *Goldf.*
——, n. s.
Emarginula planicostula, *Deslong.*
*—— scalaris, *Sow.*
*—— tricarinata, *Sow.*
*——, three new species.
*Fissurella acuta, *Deslong.*
——, n. s.
Fusus carinatus, *Roem.*
Littorina, n. s.
Melania, n. s.
*Monodonta Lyellii (Nerita), *Archiac.*
*—— sulcosa (Nerita), *Ziet.*
*——, two new species.
*Naticella decussata (Natica), *Münst.*
Natica adducta, *Phill.*
Nerita costata, *Sow.*
*—— pulla, *Roem.*
Nerinæa, two new species.
Patella nitida, *Deslong.*
*—— rugosa, *Sow.*
*——, two new species †.
*Pileolus lævis, *Sow.*
——, n. s.
Phasianella, n. s.
*Rimula clathrata, *Sow.*
*Rissoa lævis, *Sow.*
*—— obliquata, *Sow.*
Rostellaria, n. s.
Scalaria, n. s.
Solarium, four new species ‡.
Trochus monilitectus, *Phill.*
——, five new species.
Turbo, two new species.

Some of the species in the foregoing table are also met with in the Great Oolite of Wiltshire. A few are here and there, though rarely found, in the *whole* of the freestone, and others range indiscriminately throughout the group, especially *Arca ovata, Avicula complicata, Pecten vimineus, Cidaris subangularis,* and *Echinus germinans.* In addition to these, there are several others which have not been determined; and the following appear, as far as is at present known, to be among the more characteristic species limited to the freestone:—

† One of these with a smooth shell, not uncommon in the shelly freestone, is described as *P. lata* by Mr. Sowerby, but Mr. Lycett identifies it with a new species in the great oolite. It has generally lost the shell.

It is worthy of notice, that the collection of shells from the more fossiliferous portions of the freestone, and of which so large a proportion agree specifically with forms in the great oolite, presents an isolated series, the greater number being evidently peculiar to the freestone, and affording many distinctive and remarkable characters.

‡ *Solarium* occurs in the oolite marl near Stroud, in the coral bed (oolite marl) at Crickley, and in the lower strata of the inferior oolite at Dundry, and near Ilminster, but the species differ materially.

Arca lata.
——, n. s.
Astarte depressa.
——, two new species.
Avicula, n. s.
Cucullæa, four new species.
Corbula, n. s.
Corbis, n. s.
Cytherea, n. s.
Donax ?, two new species.
Gervillia, two new species.
Hiatella, n. s.
Lima, n. s.
Opis, n. s.
Placuna, n. s.
Pecten, several small species, two of which are new.
Psammobia lævigata.
Trigonia, n. s.
Venus trapeziformis.
Cerithium, several new species.
Cylindrites, two new species.
Emarginula, two new species.
Fissurella, one new species.
Nerinæa, n. s.
Patella, two new species.
Phasianella.
Rostellaria, n. s.

It will be observed that the *bivalves* generally preponderate over the *univalves*, and the Gasteropoda are proportionally much less numerous than they are in the Great Oolite at Minchinhampton.

Among the Conchifera ..... 38 } are identical with Great Oolite*
And of the Gasteropoda ... 15 } species.

Total 53 species.

The number of new species determined by Mr. Lycett amounts to 75.

At the suggestion and with the sanction of Mr. Strickland, I append his notes on the Leckhampton Section, which help much to illustrate the preceding observations, and to which they form a valuable supplement.

Notes on a Section of LECKHAMPTON HILL. By H. E. STRICKLAND, Esq., M.A., F.G.S.

The well-known promontory of the Cotswolds, called Leckhampton Hill, affords probably the best locality in Gloucestershire for studying the relative position of the various beds of the inferior oolite and subjacent lias. From its great height and steepness, the entire series of the oolite is admirably exposed to view, and the extensive quarries from which Cheltenham has been mainly built, afford every facility for examining the formation. The geologists of Cheltenham and the neighbourhood are well acquainted practically with the subdivisions of the strata and their organic contents, but no exact definitions or precise measurements of these strata have, I believe, ever yet been made. Mr. Buckman's 'Chart' contains a section of Leckhampton Hill, and is valuable for its descriptions of the mineral character and organic remains of some of the beds. But it does not attempt to exhibit all the subdivisions of the oolite, or to show their absolute and relative thicknesses. It appeared therefore desirable that a more elaborate survey should be made, and with this object I gladly availed myself of the aid of the Rev. A. D. Stacpoole of Ox-

* Several of the small shells collected by Mr. Morris in the Barnack Rag, which is considered to belong to the Great Oolite, are identical with some in the list above given.

ford, whose skill in the use of surveying instruments was of great service. Where the strata were exposed in a vertical escarpment and were accessible, they were accurately measured, but in other cases their thickness could only be ascertained by means of the sextant. By putting together the varied observations thus obtained, we constructed the section given at p. 242, *supra*. It is drawn on a uniform scale of height and distance, so that it exhibits the precise profile of Leckhampton Hill, without those exaggerations seen in others where two scales are adopted. The height of this hill above the sea has been ascertained by the Officers of the Ordnance Survey to be 978 feet (see Annals and Magazine of Natural History, Second Series, vol. v. p. 257). I will now proceed to enumerate the strata here observed, adopting, as far as they go, the names employed in Sir R. Murchison's 'Geology of Cheltenham.'

(1.) Trigonia grit: so called from the abundance of Trigoniæ which it contains. It is better exhibited in other localities, especially at Cold Comfort Farm, but it may be seen in the quarries on the highest part of Leckhampton Hill, its thickness being about 7 feet.

(2.) Gryphite grit: characterized by the very peculiar and conspicuous shell "*Gryphæa cymbium*." Extensively quarried on the summit of the hill, and used for roads, building walls, &c. Thickness 7 feet.

(3.) Beds of brown rubbly oolite, not employed for any purpose, but exposed between the inclined planes and the Cirencester road. It contains a considerable variety of fossils. Thickness 24 feet.

(4.) Oolitic freestone, too fragmentary to be of much value for building, and apparently not distinguished by any peculiar fossils. 26 feet.

(5.) Oolite marl, consisting of soft, whitish oolitic stone containing much aluminous matter and some beautifully preserved fossils, and especially characterized by the very peculiar *Terebratula fimbria*. 17 feet.

(6.) Beneath the marl, the strata for more than 100 feet consist of compact light-coloured oolite. The upper portion forms the best building-stone, and has been extensively quarried; hence it is more especially distinguished by the name of "freestone." Its thickness at the point where we measured it was 31 feet 6 inches. The lower part of this oolitic mass is coarser and more variable in texture, and is hence more rarely quarried. Numerous and beautiful fossils may be procured in it, but only by great patience and perseverance. The resemblance of these and their matrix, to those of the great oolite on Minchinhampton Common, is very remarkable, and caused considerable discussion among geologists until the distinctness of the two strata was absolutely demonstrated. This part of the series is 75 feet thick, and is locally known by the name of "roestone."

(7.) Ferruginous beds, consisting of coarse oolite in the upper part, and of the very peculiar, large-grained oolite or *Pisolite* ("Pea-grit") in the lower. A few miles to the south the Pisolite disappears, and is replaced near Painswick and at Haresfield Hill by strata containing ferruginous oolitic grains in a brown paste. This is the precise equivalent of the well-known oolite of Dundry near Bristol, which may

be recognized as far off as Bridport on the Dorset coast. At Leckhampton the Pisolite rests on a few feet of ferruginous oolite and sand. The total thickness of this portion of the series is 42 feet.

(8.) Immediately below this sand we find in the gravel-pits on the side of the hill, an abrupt transition to beds of bluish clay. This is the uppermost portion of the upper lias, the thickness of which cannot be easily measured for want of sections, but which may be estimated at 180 feet.

(9.) Marlstone. This stratum, so rich in fossils at Bredon and Alderton Hills, is not exposed to view on Leckhampton Hill, but is probably indicated by the low ridge which rises to the south of Leckhampton Church. Its thickness may be estimated at 50 feet.

(10.) Lower lias. It would be a matter of great difficulty to determine accurately the thickness of this formation, from the base of the marlstone to the top of the new red marls. Its depth is undoubtedly very great, and it is divided into several distinct zones, well-marked by peculiar fossils. From an examination of numerous sections made during many years, I am disposed to estimate its total thickness at probably between 500 and 600 feet.

By adopting Leckhampton Hill as our standard of comparison with other places where the inferior oolite is exposed, we may trace (as Mr. Brodie has already done) the enlargement of some strata, the thinning out of others, and the introduction of new ones. We shall find also considerable variations in the organic contents of the same stratum at different localities, whereby we may be enabled to study the causes which operated in the distribution of animal life in the ancient seas.

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3. *On the* Volcanic Rocks *of* Northern Mexico. By Lieut. G. F. Ruxton.

[Extract of a letter to Prof. C. G. B. Daubeny, M.D., F.R.S., G.S.]

I need scarcely apologize for drawing your attention to the fact, which I am enabled to state from personal observation, that along the whole ridge of the Sierra Madre and the continuous system of table-lands lying along that ridge which may be said to connect the two great chains of the Andes and Rocky Mountains, there are very many tracts which have been subjected to volcanic agency; and from Durango to the point where the Sierra Madre joins the main chain of the Rocky Mountains, on the ridge itself and the plains contiguous to its eastern base, the tabular formation of the bluffs and hills, called *Mesas* (tables) by the Mexicans, is a characteristic feature of the country; such Mesas being formed of basaltic lava and scoriæ.

At a point nearly 800 miles north of Durango, the Rio Bravo del Norte forces its way for upwards of fifty miles through a volcanic plain, and in the most north-western portion of New Mexico (Proper), but still on the eastern side of the Sierra Nevada, volcanic districts are frequently met with.

The regions north of Durango having been rarely, if ever, visited by Europeans, the information concerning them must necessarily be exceedingly meagre.

4. *On the Discovery of a nearly perfect Skeleton of the* MASTODON ANGUSTIDENS *near* ASTI *in* PIEDMONT. By Professor EUGENE SISMONDA.

[Extract of a letter to Sir R. I. Murchison, V.P.G.S.]

"IN the excavations made by cutting the railroad from Turin to Genoa, a skeleton almost entire of the *Mastodon angustidens* has been discovered, about six leagues from Turin, and not far from Asti. Unfortunately, the remains having been deposited on a sort of plastic clay and covered by porous sand, had been for so many ages exposed to the influence of water which lodged upon the clay, that some of the bones require considerable restoration. But notwithstanding this defect, the Royal Museum of Turin may perhaps now flatter itself, that it possesses the most perfect skeleton of the Mastodon as yet found in Europe. The formation in which it was interred is of fresh-water character, and contains a *Helix* and a *Clausilia* belonging to the great ancient alluvial (drift) formation of Italy. I am now preparing a description of these valuable remains, the different parts of which are not yet sufficiently cleaned and detached from the matrix to enable me to tell you precisely all we possess. I can, however, inform you that the following bones exist. A great part of the upper jaw with the molars, a complete lower jaw, several fragments of the skull, one entire tusk, two metres and a half long, and the larger portion of the other tusk, some cervical vertebræ, and most of the dorsal, almost all the ribs, though much broken, a scapula, the two humeri, one fibula, the two femora, the tibiæ, one cubitus, several fragments of the feet, and a part of the pelvis," &c. &c.

In addition to this, Professor Angelo Sismonda, the well-known geologist and brother of the palæontologist, writes to Sir R. Murchison, that in assisting at the exhumation of this fine relic he more than ever convinced himself that the Subapennine or pliocene marine formation of Italy was very generally succeeded by such a freshwater deposit, viz. in Tuscany, the Vale of the Arno, Piedmont, &c.

JANUARY 23, 1850.

J. O. H. Matthews, Esq., F. C. S. Roper, Esq., and S. Clegg, Jun., Esq., were elected Fellows.

The following communication was read:—

On the Structure of the STRATA BETWEEN THE LONDON CLAY AND THE CHALK *in the* LONDON *and* HAMPSHIRE TERTIARY SYSTEMS. By JOSEPH PRESTWICH, jun., F.G.S.

PART I.

WE are indebted, early in the history of geology, to Dr. Buckland, Phillips and Conybeare, Parkinson, Warburton, Webster, and others for many valuable illustrations and descriptions of separate and detached sections, as well as for some more general details of portions,

of the London tertiary district*. Further descriptions, in which I must necessarily go over again part of the same ground, may appear in some measure superfluous; but although the relative position which the whole of the series of beds known as the *plastic clay formation* bears to the *London clay* and the *chalk*, has long been well established, and is sufficiently apparent in several sections, the exact grouping and subdivisions of these lower Eocene deposits in their entire range, by which alone the precise co-relations of the strata can be determined, have not yet I think been clearly shown.

These beds have in fact been viewed as one deposit irregularly interstratified, and the sections at Herne Bay, Upnor, Lewisham, Woolwich, and Reading have been co-related "*en masse*," but not in detail. It has of late even been considered doubtful whether the larger original divisions into *London clay* and *Plastic clay* could be maintained; whether the latter were not merely the subordinate beds of the former formation.

The object therefore of this paper is both to describe several new sections, and also to show, that the variable series of deposits forming the lower tertiaries can be divided into distinct and separate, yet not altogether independent subdivisions, each marked by different conditions, indicating ancient hydrographical and palæontological changes of some importance.

The main body of the London clay presents throughout its whole range a uniformity of mineral structure so well marked and distinct, that either by this character alone, or else by its organic remains, when present, it can almost always be readily recognized. But the case is far otherwise with the more varied deposits which intervene between the London clay and the chalk. This series is not large, yet it exhibits in different places variations in its structure and in its fauna, which render the determination of the exact parallelism between distant sections difficult. Thus below the London clay in the Isle of Wight† we find almost exclusively beds of compact mottled clays without organic remains. In the neighbourhood of Newbury and Reading are mottled clays, interstratified with beds of sand, and generally underlaid by a bed abounding with the *Ostrea Bellovacina*. At Woolwich, Charlton, and Bromley the chalk is overlaid by unfossiliferous sands, succeeded by a mixed series of clays and sands with flint pebbles, and containing numerous organic remains of freshwater and estuary origin; whilst at Herne Bay and in the Isle of Thanet there exists a thicker and more important series of sands, sometimes in part very argillaceous, at other times much mixed with green sand, and many of the beds of which abound with marine fossils,—the fluviatile beds of Woolwich, and the mottled clays of the Western districts, having in these places completely disappeared.

Amongst the first questions therefore which arise, are,—with which portion of the Woolwich series are the mottled clays of the Reading

* See the early volumes of the Trans. Geol. Soc. from 1811 to 1825, and Phillips and Conybeare's Geology of England. The separate references are made in the course of the paper, wherever the sections have been previously described.

† See Section of Alum Bay and White Cliff Bay, in the 2nd volume of the Quart. Jour. Geol. Soc. pl. 9, strata 1 and 2.

series the equivalent, and to which precise portion of the former is the *Ostrea Bellovacina* bed of the latter to be referred? what portion of the Isle of Wight strata represents the fossiliferous conglomerates of the neighbourhood of Bromley, and the extensive pebble-beds of Blackheath and Addington? and of what portions of the Herne Bay section are all the above-mentioned strata individually and jointly to be considered the representatives—if represented at all? The relative position of the Northaw "*Ostrea*" bed, and of the Kyson bed with its remains of the Monkey, in reference to those above mentioned, is also to be determined.

I am aware that the series of mottled clays at Reading with their overlying seam of marine shells, has been referred as a whole to the series of sands, clays, and pebbles at Woolwich and Charlton, the marine upper bed at the former place being viewed as the representative of the fluviatile and estuary beds of the two latter; the thin but uniform stratum of impure green sand with large flints, which in both localities immediately overlies the chalk, at Reading with, and at Woolwich without, the *Ostrea Bellovacina*, being considered synchronous. It is true, that the series in each of these localities bear on a broad scale the same relative position to the chalk and the London clay; but, this admitted, it remains to be ascertained whether the whole of these series belong to one and the same group, occupying in an irregular manner this space in geological time, and varying in its thickness, in its mineral character, and in its organisms, without determinable order; or whether there are not subdivisions, each traceable over certain areas, and exhibiting essential modifications in structure, but yet invariably holding the same relative position one to another, and which may lead to the establishment of a more connected order and definite sequence in the phænomena. In this inquiry, we must take into consideration the physical condition of the surface at that early Eocene period, and ascertain how far it is probable that, as with the more recent London clay, which spreads uniformly over the whole area, the several and distant beds in this lower series originated in one sea, and were therefore likely to extend over co-extensive areas. The determination of this point is of material importance to the question of exact synchronism of the strata.

In the Isle of Wight and in the tertiary district westward of London, the London clay consists of tenacious brown and bluish-grey clays with layers of septaria, usually most abundant in the browner clays, and with small round black flint pebbles occasionally scattered through some of the darker and more sandy portions of the clay. Immediately at its base the London clay commonly contains a greater or lesser admixture of green and yellow sands, generally mixed with rounded flint pebbles, and not unfrequently cemented by carbonate of lime into semi-concretionary tabular masses. These mixed beds however never exceed a few feet in thickness, and pass upwards rapidly into the great mass of the London clay, to which they appear to be subordinate, being clearly and sharply separable from the sands and mottled clays both in mineral and zoological characters. (See Sections 1 to 6.) To the eastward of London, as at New Cross, Upnor, and Herne Bay, the mass of the London clay is apparently

equally distinct, exhibiting a strong massive clay, reposing abruptly and without passage on a thick series of yellow and ash-coloured sands, with many subordinate beds of pebbles, and a few laminated clays, and containing a varied and irregular fauna. This series seems as independent of the London clay as do the sands and mottled clays to the westward of London; but it is a question whether the thin basement conglomerate bed, which in the latter district merges into the London clay, and has a character so entirely distinct from that of the underlying beds, does not, as it trends eastward, assume a lithological structure more entirely different from that of the London clay and not passing into it, but, on the contrary, assimilating so closely to the underlying sandy series, that in general appearance it seems an upper and subordinate member thereof. (See Sections 10 & 11.) I believe, however, this bed to be part rather of the *London clay* than of the so-called *plastic clays* with which it has been grouped. But although belonging to the former rather than to the latter, yet it forms in some of its characters a stratum separable from both. I purpose therefore to describe this bed ("*c*" of the Sections) before proceeding to an examination of the underlying deposits. This will follow in natural order the general description I have before given of the London clay; and as this will of itself constitute a subject of some extent, which it is important to our argument to examine in detail, I will subdivide the general question under different heads, and begin with this first division of it.

1st Division. *On the Basement bed of the London Clay* ("*c*").

In the fine section of Alum Bay there may be seen, at a distance of about ninety-four feet from the chalk, a thin and insignificant layer, not a foot thick, of rather large (egg-sized), rounded, black flint pebbles imbedded in a scanty yellow sand and brown clay, and separating the important mass of the London clay on the one side from that of the mottled clays on the other, and to the former of which it forms the base*. This pebble-band contains a few organic remains, of which the most common are the teeth of a species of *Lamna*; the *Ditrupa plana* also occurs, and traces of several species of shells. It reposes upon a somewhat uneven and worn surface of the underlying stratum. Small and unimportant, however, as this bed here is, it is nevertheless remarkable for the extent of its range, the uniformity of its lithological characters, and the permanence of its organic remains,—conditions of the more value from its position between the two main members of the Eocene series. It forms an excellent base-line, and its characters are so well marked, that it can be traced without much difficulty from the Isle of Wight to Woodbridge in Suffolk, a distance in a straight line of above 160 miles from S.W. to N.E.

In a former paper, when discussing the connection of the London

* See Section of Alum Bay, Quart. Journ. Geol. Soc. vol. ii. pl. 9. fig. 1. I have since applied the term "London Clay" to the division there called "Bognor beds," and have abandoned it for the strata higher in the series (see Quart. Journ. Geol. Soc. vol. iii. p. 355).

clay of Hampshire with that of the London district, I had occasion to allude frequently to this basement bed in the Isle of Wight and in the western part of the London district. In addition to the sections of the central and eastern area of the London tertiaries, which did not then come under notice, I purpose giving a few of the leading sections I then alluded to in more detail than I could in a paper which embraced a wider subject, and to which this point was only secondary.

I will take separately the sections and lists of the organic remains at each locality, and afterwards endeavour to show their co-relation*.

To resume in the Isle of Wight with the interesting section of this bed at White Cliff Bay. (See fig. 1.)

Fig. 1.—*Section of a part of White Cliff Bay.*

b. London clay; dark brown and grey clay; in descending becomes mixed with green sand. Fossils scarce.
1
2
3
4
e.
1. Tabular septaria, with numerous fossils. 2. Mixed clay and green sand, like 4. 3. Dark green sand, full of the Ditrupa plana. 4. Brown sandy clay, much mixed with green sand, and passing downwards into a conglomerate with round flint pebbles, and partly rounded pebbles of chalk and red clay. Contains a few Ditrupa plana. 3 to 4 feet.
d. Mottled clays—dark red (upper part of).

The occurrence of pebbles of the underlying mottled red clay in the lower part of the basement of the London clay "*e*" is a fact here to be particularly noticed.

The organic remains found in this bed are as under:—

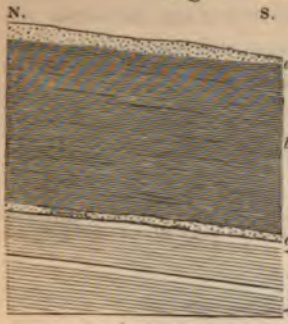
Cardium Plumsteadiense, *Sow.*
Corbula, a finely striated species.
Cytherea obliqua, *Desh.*
Ditrupa plana, *Sow.* sp.
Natica glaucinoides, *Sow.*
Traces of carbonized vegetables and wood.
Ostrea, a large undetermined species.
Pectunculus brevirostris, *Sow.*
Pyrula tricostata, *Desh.*
Rostellaria Sowerbyi, *Mant.*
Teeth of Lamnæ†.

Passing over to the northern part of the Hampshire tertiary district, the only good section of this bed that I am acquainted with was exposed in a cutting on the Railway at Clarendon Hill, three miles E.S.E. of Salisbury. (See fig. 2.)

* For an outline map of the tertiary strata, see Quart. Journ. Geol. Soc. vol. iii. pl. xiv.

† I have omitted the name of the species, as I feel in doubt as to which of Agassiz's species to refer it. It probably is the *L. elegans*, or there may be more than one species. The same species accompany this bed throughout its entire range.

Fig. 2*.—*Section at Clarendon Hill.*


N.
S.
a. Ochreous flint gravel.
b. London clay; dark bluish grey sandy clays with numerous Panopæa, Ostreæ, and Pinnæ.
c. Large tabular masses; composed, some of almost a pure green sand, and others of a coarse ochreous sand, with a calcareous cement. A few rather small round flint pebbles are scattered through these blocks.
d. Alternating thin beds of sand and thick beds of mottled clay; chiefly red.

The chalk outcrops lower down the hill at a depth apparently of about forty to fifty feet beneath "*c*."

Organic remains of stratum "c," at Clarendon Hill.

Buccinum (? ambiguum, *Desh.*).
——, n. sp., large and globose.
Cancellaria læviuscula, *Desh.*
Cardium nitens, *Sow.*
——, n. sp., α.
Corbula longirostris, *Desh.*
Cytherea obliqua, *Desh.*
—— ovalis, var. ?, *Sow.*
—— lævigata, var. *a*?, *Lamk.*
Ditrupa plana, *Sow.* sp.
Fusus tuberosus, *Sow.*
——, n. sp., with plain costæ.
——, n. sp., large and smooth.
Natica glaucinoides, *Sow.*
—— Hantoniensis, *Pilk.*
Nucula, a small species.
Ostrea, large undetermined species.
Pectunculus brevirostris, *Sow.*
—— Plumsteadiensis, *Sow.*
Pyrula tricostata, *Desh.*
Pleurotoma comma, *Sow.*
Rostellaria Sowerbyi, *Mant.*
Tellina.
Turritella?
Teeth of Lamnæ.
Carbonized pieces of wood.

The fossils are extremely abundant, and occur in large blocks of clay and green sand with a calcareous cement. The most common species are the *Ditrupa plana, Natica glaucinoides* and *N. Hantoniensis, Cytherea obliqua, Pectunculus brevirostris, Rostellaria Sowerbyi,* and *Pyrula tricostata.*

It is not my intention to trace this bed any further in Hampshire: I may however observe, that I there know of no other good section of it. I have seen it, but not well exhibited, at Padnell, in Bere Forest, and also on the railway near Fareham.

Crossing the intervening chalk district to the most westerly extension of the London tertiaries, the first point, where we meet with some uncertain indications, without sections, of the basement bed of the London clay, is, capping the summit of Bagshot Hill between Great Bedwin and Hungerford. It is better exposed between Hungerford and Newbury, near the summit of Pebble Hill, one mile south of Kintbury. (See fig. 3.)

* This and the following sections (figs. 2 to 20) are all drawn upon the same scale; viz. 1 inch represents a thickness of 20 feet. Section fig. 1 is an exception to the rule. It is the fig. given in the Journal of the Society, vol. iii. p. 362, and is upon a much larger scale.

Fig. 3.—*Section at Pebble Hill.*

a. Ochreous gravel, composed chiefly of round flint pebbles.

b. London clay; blackish sandy clay, passing downwards into brown clay; round flint pebbles and very friable shells dispersed irregularly throughout.

c. Coarse ferruginous sand, full of round flint pebbles 1 to 12 inches in diameter; some chalk pebbles; many of the flint pebbles decomposed throughout into a white friable structure. This bed frequently passes into an iron sandstone conglomerate.

d. Mottled clays, chiefly of a light greenish colour, overlying an irregular bed of sand, below which succeed other irregular beds of mottled clays.

The chalk crops out about 60 feet below "*c*."

Stratum "*c*" here contains no organic remains, except the teeth of the same species of *Lamnæ* which occur at Clarendon Hill, and which we shall find to accompany this bed very constantly in the London district. This point forms the apex of a long and roughly triangular area, occupied by the tertiary eocene strata, and stretching eastward to the German Ocean. The southern side of this triangle extends from Pebble Hill to the cliff near the Reculvers in Kent, a distance of about 100 miles, and the northern side from Pebble Hill to Woodbridge in Suffolk, nearly 140 miles. Owing to the thickness of the London clay in the tract between these two lines, it is only by well-sections that we can learn anything of its basement bed. If however we follow the outcrop of the beds, we shall find this stratum coming to the surface with much regularity along the southern edge of the tertiary area, whilst along its northern edge it forms a more broken and irregular line. This arises from the tertiary deposits being, on the south from Inkpen to Croydon, tilted up at a considerable angle against the ridge of chalk hills, which throws them out suddenly and sharply, whereas towards the north they rise gradually, and form with the chalk a tolerably regularly inclined plane from their outcrop from below the London clay to the edge of the chalk escarpment, disappearing only gradually according as the chalk attains a higher level, and adapting themselves to all the irregularities and variations of the surface.

On this latter side, therefore, the tertiary strata often form hills overlooking the chalk district, whilst on the south side the chalk hills almost constantly command fine and extensive views over the tertiary area.

In following the basement bed of the London clay eastward from Pebble Hill, it will be convenient to take these two sides of the triangle separately. It happens that many of the beds between the chalk and the London clay are of considerable economical value for their sands, and tile and pottery clays, and they are consequently worked to a great extent. A zone of brick and tile fields in fact marks their outcrop from Marlborough to Ewell on the one side, and to Woodbridge on the other. We are thus furnished with a series of sections, such as we obtain in no other part of the English ter-

tiaries. They enable us to trace the sands and mottled clays without much difficulty over a large district; but although these lower tertiary beds are so frequently worked, and their relation to the chalk underlying them is often shown, the sections nevertheless rarely exhibit the overlying lower beds of the London clay.

At the base of the chalk hills between Inkpen and Basingstoke there are a considerable number of sections, more or less perfect, of these lower tertiary beds. One of the best and most illustrative is in a brick-field at Itchingswell, two miles westward of Kingsclere. (See fig. 4.)

Fig. 4.—*Section at Itchingswell.*

b. London clay; upper part bluish grey passing down into brown; sandy at base; a few calcareous concretions, and a few fossils. (The lower part of this bed should perhaps be included in "*c*.")

c. Ferruginous sand and iron sandstone mixed with green sand, and full of round flint pebbles, varying in size from 1 to 14 inches in diameter; no fossils except a few teeth of *Lamnæ*.

d. Mottled clay and sands.

The chalk outcrops at a distance of about 50 feet from "*c*."

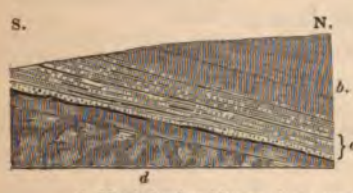
Organic remains of stratum "c," at Itchingswell.

Cancellaria læviuscula, *Desh.*
Cytherea obliqua, *Desh.*
Ditrupa plana, *Sow.* sp.
Ostrea, large species.
Nucula.
Panopæa intermedia, *Sow.*
Pectunculus Plumsteadiensis, *Sow.*

These fossils occur at the base of "*b*," just above "*c*."

A section at Chinham, one mile and a half north-east of Basingstoke, on the line of railway from that town to Reading, showed the basement conglomerate bed passing gradually upwards into the mass of the London clay. The organic remains were numerous, but in a very friable state. (See fig. 5.)

Fig. 5.—*Section at Chinham.*



b. London clay; thin-bedded brown clay without fossils passing downwards into dirty yellow sands with seams of brown clay, and then into a sandy light-coloured clay "*c*," with seams of green sand and a few round flint pebbles occasionally concreted into small flat masses by carbonate of lime; traces of vegetable matter; shells abundant in the seams and patches of green sand, but very friable and generally in the state of casts. Average thickness of "*c*" 5 feet.

d. Mottled red and brown clays; upper surface slightly uneven and worn.

The junction with the chalk, which crops out immediately on the opposite side of the small valley formed in these lower sands, is not exposed.

Organic remains of stratum "c," at Chinham.

Cassidaria striata, *Sow.*
Cardium Plumsteadiense, *Sow.*
Cytherea ovalis, var.?, *Sow.*
Ditrupa plana, *Sow.* sp.
Fusus, small species.
Modiola elegans, *Sow.*
Natica glaucinoides, *Sow.*
—— Hantoniensis, *Pilk.*

Ostrea, small species.
Pectunculus Plumsteadiensis, *Sow.*
Pyrula tricostata, *Desh.*
Rostellaria?
Teeth of Lamnæ.

Hence this bed may be traced by Old Basing, Odiham, Farnham*, to Guildford, where an interesting section of it was exposed on the line of railroad a few hundred feet north of the present station. (See fig. 6.)

Fig. 6.—*Section at Guildford.*

Brown London clay without fossils, passing downwards into yellowish sand, and then into "*c*," mixed yellow sand and clay and green sand; full of round flint pebbles, but without organic remains.

1. Yellow sandy clay full of shells, perfect and in fragments (*Cyrena*, *Cerithium*, and *Ostrea*).
2. Very dark clay mottled red.
3. Light greenish clay mottled red, passing down into mottled clays of different colours and sands.

The junction with the chalk is not exposed. The outcrop of this latter is however seen a few yards nearer Guildford. This section is of much interest from the circumstance of a thin layer (1 of *d*) of the fluviatile shells of the Woolwich beds occurring on the top of the mottled clays and under stratum "*c*." This is the most westerly point at which these shells have, I believe, been yet observed. They consist of several species of *Cyrena*, *Cerithium*, and *Ostrea*. The line of separation between beds "*c*" and "*d*" is waved and irregular.

Passing by Leatherhead, Epsom, and Ewell to Croydon, no good section of this bed is exhibited; indications of it occur only here and there. It then trends suddenly to the north, but still it is not exposed until we reach Lewisham, where, in one of the pits near the summit of Loam-pit Hill, the London clay, with a thin basement conglomerate bed, may be seen overlying a bed of light-coloured sand. (See fig. 7.)

Fig. 7.—*Section at Loam-pit Hill.*

a. Brown clay mixed with flint gravel.

b. London clay; laminated brown clay with septaria occasionally. No organic remains yet found.

c. Round flint pebbles in brown clay, and in places sand. No organic remains.

d. Light yellow and whitish sands. 8 to 10 feet exposed.

The pits lower down the hill show in disconnected sections the

* Two miles W.N.W. from this town I have recently found in a brook above Lower Old Park Farm, detached blocks with numerous fossils of this "Basement bed."

series of the Woolwich fluviatile beds, and the underlying sands reposing upon the chalk*.

At Counter Hill, stratum "*c*" is two feet thick, and shows very distinctly the irregular and worn surface of "*d*," on which it reposes; "*d*" is there thinner, of a nearly pure white colour, and contains numerous small patches of small round flint pebbles. On the line of the Croydon Railway immediately south of the New Cross Station, is a section of this bed, which has already been described by Mr. Warburton in 1844†. For the sake however of showing its connexion with the foregoing details, I here give a diagram of that part of the cutting, showing the conglomerate bed at the base of the London clay. (See fig. 8.)

Fig. 8.—*Section at New Cross.*

b. London clay; tough brown clay with septaria, but without organic remains.

c. Dark ochreous sand full of round flint pebbles. No organic remains.

d. Yellow sand and clays forming the upper part of the series of the Woolwich fluviatile beds hereafter to be described.

The chalk has been reached at a depth of about 100 feet beneath stratum "*c*."

We must now make a slight deviation in order to examine a well-section at Hampstead, the particulars of which were communicated to the Geological Society in 1834 by Mr. Wetherell‡. It was shown, that the London clay was there underlaid by a compact rock, five feet thick, formed of green sand, with numerous round flint pebbles, and cemented by carbonate of lime, reposing upon a series of sands and mottled clays overlying the chalk.

The following are the organic remains he gives from this rock:—

Rostellaria lucida, *Sow.* (? Sowerbyi, *Mant.*)
Natica glaucinoides, *Sow.*
Nucula.
Panopæa intermedia, *Sow.*
Cardium nitens, *Sow.*
Pleurotoma.
Venus incrassata, *Desh.* sp. (? Cytherea obliqua, *Desh.*)
Scales and teeth of fishes.
Lignite.

We are now arrived at a point of considerable difficulty. So far the range of this stratum has been regular, and the line of demarcation between it and the upper part of the mottled clays and sands has been well-marked; but on reaching the neighbourhood of Croydon and London a different order of things commences. The mottled clays disappear except in small quantities, and in a few places; large and thick beds of round pebbles set in, interstratified with a peculiar series of fluviatile and freshwater beds. The London clay recedes further to the north, leaving a large and more

* For a better section than any now exposed of these beds, see Dr. Buckland's paper in the Trans. Geol. Soc. vol. iv. p. 285; also Phillips and Conybeare's Outlines of the Geology of England, p. 49.

† Quarterly Journal of the Geological Society, vol. i. p. 172. See also Phillips and Conybeare, Geology of England, p. 48.

‡ Trans. Geol. Soc. 2nd Series, vol. v. p. 131.

hilly district, stretching from Croydon to beyond Gravesend, occupied solely by this sandy and pebbly series reposing on a base of chalk, and only in a very few cases showing a capping of the London clay. The difficulty is, whether we are to consider any of the peculiar fossiliferous, sandy or conglomerate beds of Woolwich, Bromley, and adjacent districts as a fuller development of the basement stratum of the London clay, or whether they all belong to a distinct and underlying series. I am rather inclined, on structural evidence, to the latter opinion; nevertheless, on palæontological grounds it might be presumed that a passage here exists between the two series. We however yet feel the want of a few good sections to settle clearly this point, to which I shall have occasion to revert more fully in another part of this paper.

At various points beneath the outlier of London clay at Shooter's Hill are indications of the basement pebbly bed of the London clay; and some years since there seems to have been at Plumstead a deeper and better section than any now existing; for in some of the early numbers of the 'Mineral Conchology,' Mr. Sowerby described a group of shells from this locality which bore a strong general resemblance to those of the bed we are describing. The following is a list of the shells he enumerates:—

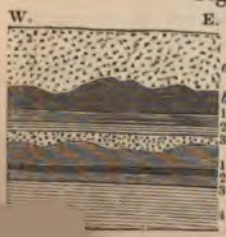
Cardium Plumsteadiense, *Sow.*
Calyptræa trochiformis, *Lamk.*
Cerithium variabile, *Desh.*
Fusus latus, *Sow.* sp.
—— costatus, *Sow.*
—— gradatus, *Sow.* sp.
Fusus labiatus, *Sow.* sp.
Melania inquinata, *Defr.*
Neritina uniplicata, *Sow.*
Panopæa intermedia, *Sow.*
Pectunculus Plumsteadiensis, *Sow.*
Planorbis (?) hemistoma, *Sow.*

Mr. Morris informs me that he has here found casts apparently of the *Cyprina Morrisii*.

From Mr. Sowerby's description, I cannot learn whether the fossils were all found in the same bed; I should be inclined to believe that they were not. The *Planorbis hemistoma*, *Neritina uniplicata*, and some species of *Fusus*, I have never found associated with the *Panopæa intermedia* and *Cardium Plumsteadiense*, so characteristic of the basement bed of the London clay. Still, if this bed was here accumulated under more fluviatile conditions, there would be no valid objection to such an association of organic remains in this part of the series.

About six miles to the north-west of this spot, a cutting on the Eastern Counties Railway, at Maryland Point, near Stratford-le-Bow, exposed a very illustrative section. (See fig. 9.)

Fig. 9.—*Section near Stratford.*



a. Ochreous flint gravel.

b. Brown clay (lower part of London clay?).

c. 1. Clayey green sand. 2. Yellow and ochreous sand. 3. Yellow and ochreous sand, with round flint pebbles and numerous fossils. It occasionally forms calcareous concreted masses.

d. 1 to 3. Brown, dark grey and yellow clays. 4. Yellow sand (5 feet), reposing upon a considerable thickness of mottled clays not exposed.

Organic remains of stratum "c," at Maryland Point.

Cardium Plumsteadiense, *Sow.*
Cytherea obliqua, *Desh.*
Calyptræa trochiformis, *Lamk.*
Fusus.
Melania inquinata, *Defr.*
Natica glaucinoides, *Sow.*
Ostrea Bellovacina, *Lam.*
Pectunculus brevirostris, *Sow.*
Pectunculus Plumsteadiensis, *Sow.*
Pleurotoma, a small ribbed species.
Rostellaria Sowerbyi, *Mant.*
Tellina ?
Scalaria.
Teeth of Lamnæ.
A boring Mollusk, probably a Lithodomus.

It will be observed that this bed is here as well characterized as at Clarendon Hill or Chinham, and that, with the exception of a single specimen of the *Melania inquinata*, its fauna does not at all resemble that of the Woolwich fluviatile beds. This solitary specimen had also the appearance of having been rolled and worn.

The low country along which this bed outcrops from Stratford to Horndon is covered with gravel and exhibits no sections. Some years since, however, a group of shells, similar to the above, was found at Stifford Bridge near Purfleet, and specimens of them are, I am informed by Mr. Morris, now in the Geological Museum at Cambridge.

On the south side of the Thames, another outlier of the London clay exists, I believe, on the Swanscombe Hills near Greenhithe, but although I have examined them closely, I have not been able to meet with a section of the basement beds.

We next arrive at the fine sections at Upnor on the banks of the Medway two miles north of Rochester. We there have nearly all the beds between the London clay and the chalk exposed in a few large sections. For the present it will be sufficient to exhibit the upper part of the section on the banks of the Medway, a short distance beyond the Castle*. (See fig. 10.)

Fig. 10.—*Section at Upnor.*

b. London clay; upper part dark brown and very tenacious, passing down into sandy lighter coloured beds. No organic remains have been yet found in it.

c. 1. Brown clay and ochreous sand, with traces of lignite. 2. Light greenish sand, with a few patches of friable shells. 3. Fine yellow sand, with a few shells. 4. Indurated clay, with numerous shells and traces of plants. 5. Yellow sand, the upper part full of round flint pebbles, and the lower part abounding in shells. Concreted masses, full of shells, not uncommon.

d. 1. Light yellow and whitish sand; upper surface indented by stratum "*c*;" contains a few shells (*Ostrea* and *Cyrena*) in irregular patches, and occasionally an underlayer of large Ostreæ. 2. A series of dark tough clays, with subordinate lignite and beds full of the fluviatile shells of Woolwich. 3. Variable yellow sands, reaching probably to the chalk, at a depth of 50 or 60 feet below "*c*."

* This section is described by Mr. Morris in the Proc. Geol. Soc. vol. ii. p. 451.

Organic remains of stratum "c," at Upnor.

Cardium nitens, *Sow.*
—— Plumsteadiense? *Sow.*
—— n. sp. α.
Cytherea or Cyprina, large gibbous sp.
Calyptræa trochiformis? *Lamk.*
Cerithium variabile, *Desh.*
Cyrena cuneiformis, *Sow.*
—— obovata, *Sow.* var.
—— tellinella?, *Fer.*
Cytherea ovalis, var.?, *Sow.*
Glycimeris or Panopæa.
Melania inquinata, *Defr.*
Natica Hantoniensis? *Pilk.*
Ostrea.
Pectunculus Plumsteadiensis, *Sow.*
Pleurotoma.
Rostellaria Sowerbyi, *Mant.*
Teeth of Lamnæ.

The undoubted admixture at this spot of several species of estuary shells of the Woolwich beds with the ordinary fauna of stratum "*c*" is to be noticed.

Thence through Sittingbourne to Faversham, I have met with no section of this bed. In the year 1841 Mr. Trimmer* called attention to a fossiliferous sandstone overlying the lower sands which repose on the chalk, on the hill above Boughton between Faversham and Canterbury, and mentions the occurrence there of four species of mollusks. I visited this locality with Mr. Rees in 1843, and we obtained from it a considerable number of other fossils, but owing to the state in which they are preserved, the following list must be received with some doubt. The bed consists of layers of very hard and compact siliceous sandstone with subordinate bands of iron sandstone. One of the upper seams of the latter contains rounded flint pebbles, and abounds with extremely well-marked impressions and casts of shells, but the substance of the shells is in all cases removed. The superposition of the bed is not shown. It is about five feet thick. At a short distance above it the London clay appears, and below it, in the valley, the chalk outcrops.

Organic remains of "c," near Boughton.

Astarte.
Calyptræa trochiformis, *Lamk.*
Cardium nitens, *Sow.*
—— Plumsteadiense, *Sow.*
——, n. sp. α.
Cerithium variabile, *Desh.*
Cyrena cuneiformis, *Sow.*
—— obovata?, *Sow.*
Corbula longirostris, *Desh.*
Cytherea ovalis, var.?, *Sow.*
Cytherea or Cyprina, a large gibbous sp.
Fusus latus? *Sow.* sp.
——, long narrow species, same as at Upnor.
——, n. sp., same as the Hedgerley sp.
Melania inquinata, *Defr.*
Natica glaucinoides, *Sow.*
Panopæa intermedia, *Sow.*
Pectunculus brevirostris, *Sow.*
—— Plumsteadiensis, *Sow.*
Pyrula?
Rostellaria Sowerbyi, *Mant.*

The estuary species of mollusks are here less numerous than at Upnor, and the marine species show an increase.

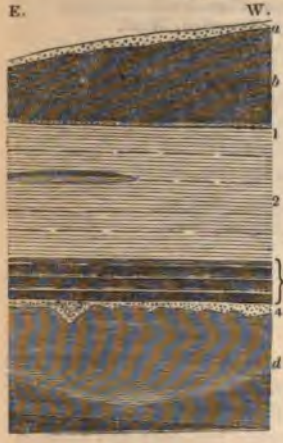
This bed thence passes by the north of Canterbury to the cliffs between Herne Bay and the Reculvers†, where a remarkably fine section of the lower part of the London clay and of a large portion of the underlying strata is exposed. These latter here put on a character very different to any we have hitherto observed. Both the fluviatile

* Proc. Geol. Soc. vol iii. p. 457.

† See paper by Mr. W. Richardson, Proc. Geol. Soc. vol. ii. p. 78; also the paper before quoted of Mr. Morris.

beds of Woolwich as well as the mottled clays are entirely wanting. Still the physical or palæontological characters are such as to warrant our considering as the basement bed of the London clay the twenty feet of sands immediately underlying the London clay, although there is here no passage between them. This bed is well exhibited in the centre of the cliff east and west of the ravine at Bishopstoke, two miles east of Herne Bay. (See fig. 11.)

Fig. 11.—*Section near Herne Bay.*



a. Brown and yellow clay, more or less mixed with ochreous flint gravel.

b. London clay; upper beds of a brown colour, and with a few small septaria covered with vermiform impressions, passing down into laminated dark grey clay, more or less sandy, with carbonized vegetable matter. Traces of *Ditrupa plana* and of two species of *Nummulites* occur in the lower part of this clay; other fossils are extremely scarce.

c. 1. Thin irregular seam of green sand; ferruginous clay and a few round flint pebbles, 2 to 3 inches. 2. Very light yellow sands with tabular concreted masses of sandstone and iron sandstone; these are frequently overlaid by a mass corresponding in size of dark clay; very friable shells are irregularly dispersed throughout this bed in small layers and in patches; on the under side of the blocks they are particularly abundant, casts chiefly. 3 & 4. Small flint pebbles with a very irregular series of thin beds of clay and of ferruginous sandstone full of casts of shells. Teeth, vertebræ and bones of fishes of frequent occurrence.

d. Light greenish clayey sands; upper surface worn and indented by the pebble bed above. Beneath are some very fossiliferous clayey sands.

Organic remains of "c," in the Herne Bay cliffs.

Astarte.
Buccinum junceum, *Sow.*
Cardium nitens, *Sow.*
—— Plumsteadiense, *Sow.*
——, n. sp. *α*.
Cerithium variabile, *Desh.*
Cytherea obliqua.
—— ovalis, var. ?, *Sow.*
Cytherea or Cyprina, a large gibbous sp.
Cyprina Morrisii, *Sow.*
Corbula revoluta, *Sow.*
Fusus tuberosus ?, *Sow.*
——, n. sp.
Modiola.
Natica labellata, *Lamk.*
Natica glaucinoides, *Sow.*
—— Hantoniensis, *Pilk.*
Nucula margaritacea, var. *β*, *Desh.*
——, longer sp.
Ostrea, small sp.
Pectunculus brevirostris, *Sow.*
—— Plumsteadiensis, *Sow.*
Pleurotoma comma, *Sow.*
——, a second sp.
Pyrula.
Rostellaria Sowerbyi, *Mant.*
——, n. sp. large and striated.
Scalaria.
Vertebræ, bones and scales of fishes.
Teeth of Lamnæ.

The estuary species, it will here be observed, have almost entirely disappeared, and we have a fauna presenting a very close analogy with that of stratum "*c*" at Sonning Hill near Reading and Clarendon Hill near Salisbury. Still at Herne Bay, and more especially at Boughton and Upnor, the fauna differs in some measure from the one which I consider to be synchronous with it to the westward of London. The bed itself also appears more distinctly separable in mineral character from the London clay.

We will now return to our starting-point at Pebble Hill, and thence

follow the northern outcrop of this deposit to Woodbridge. Taking a line by Newbury and then northward of Woolhampton to Reading, I know of but one tolerable section of this bed; it occurs in a brick-field on the summit of the hill at Englefield near Theale*. The London clay caps the hill to the depth of twenty to thirty feet. It is brown and sandy, and contains at its base a band of tabular septaria, very ferruginous and containing a few rounded flint pebbles. These septaria are occasionally full of the casts of the following shells :—

Cardium.	Panopæa intermedia, *Sow.*
Calyptræa trochiformis, *Lamk.*	Pectunculus Plumsteadiensis, *Sow.*
Ditrupa plana, *Sow.* sp.	Rostellaria Sowerbyi, *Mant.*
Nucula?	Soft, brown wood in fragments.
Natica.	Teeth of Lamnæ.

The sands and mottled clays outcrop immediately under these beds, and the chalk appears at the northern base of the hill.

At Reading Mr. Rolfe has pointed out a thin stratum overlying the *Plastic clay series*, and containing the following organic remains†:

Cytherea obliqua, *Desh.*	Ditrupa plana, *Sow.* sp.
Pectunculus brevirostris, *Sow.*	Modiola elegans, *Sow.*
Natica glaucinoides, *Sow.*	

In addition to these I have found

Cardium Plumsteadiense, *Sow.*	Scalaria.
—— nitens, *Sow.*	Ostrea.

But by far the best section, and one showing a considerable length of the basement bed of the London clay, was exhibited on the line of the Great Western Railway at Sonning Hill between Reading and Twyford. The cutting, which is sixty to seventy feet deep and about a mile long, traverses the mottled clays. These are covered in the highest parts of the cutting by three to four feet of brown clay with subordinate and irregular layers of yellow sand, the whole mixed with seams and patches of greensand and with some round flint pebbles. Irregular layers and masses of these materials, cemented by carbonate of lime and full of well-preserved shells, are of common occurrence. (See fig. 12.) A thick bed of ochreous flint gravel caps the section.

Fig. 12.—*Section at Sonning Hill.*

a. Ochreous flint gravel.
b. Brown London clay, with septaria.
c. Yellow sand, with irregular seams of brown clay and green sand; a few round flint pebbles, and numerous tabular calcareous concretions. Fossils dispersed throughout, but peculiarly abundant in the calcareous blocks. Thickness varies from 4 to 5 feet.
d. Upper part of the sands and mottled clays. Surface worn and irregular.

The chalk lies at about 70 to 80 feet below "*c*," but is not exposed.

* I have found traces of this stratum at several places on the hills both to the N.E. and S.W. of Theale, but only in small road-side cuttings.

† Trans. Geol. Soc. 2nd Ser. vol. v. p. 127. The similarity of the organic remains of these beds at Reading, Watford, Hampstead, and some other places, has already been pointed out by Mr. John Morris so far back as January 1837 (Proc. Geol. Soc. vol. ii. p. 452). In the determination of the fossils of many of these lists I have to express my obligation to Mr. Morris.

Organic remains of stratum "c," at Sonning Hill.

Astarte.
Calyptræa trochiformis, *Lamk.*
Cardium Plumsteadiense, *Sow.*
—— nitens, *Sow.*
——, n. sp. *a.*
Cytherea obliqua, *Desh.*
—— ovalis, var.? *Sow.*
Ditrupa plana, *Sow.* sp.
Fusus.
Modiola elegans, *Sow.*
—— depressa, *Sow.*
Natica glaucinoides, *Sow.*
—— Hantoniensis, *Pilk.*
Nucula.
Ostrea pulchra, *Sow.*
Panopæa intermedia, *Sow.*
Pectunculus brevirostris, *Sow.*
—— Plumsteadiensis, *Sow.*
Pleurotoma.
Rostellaria Sowerbyi, *Mant.*
——, n. sp. *a.*
Scalaria.
Venericardia?
Voluta denudata? *Sow.*
Spatangus.
Teeth of Lamnæ.

The *Ditrupa plana*, *Cardium* n. sp., *Cytherea obliqua*, *Modiola elegans*, *Natica glaucinoides*, *Ostrea pulchra*, *Pectunculus brevirostris*, and the teeth of *Lamnæ*, were here particularly abundant.

The more hilly character of the country, and the slight dip of the strata, now cause the outcrop of this bed to expand over a wider area, and to take a very irregular line, which can only be followed at intervals.

At Holywell near Maidenhead a group of fossils from a bed of this age was described by Mr. Warburton* in 1821. These fossils are now in the museum of the Society, and consist of the following species:

Calyptræa trochiformis, *Lamk.*
Cardium nitens, *Sow.*
—— Plumsteadiense, *Sow.*
Cyprina or Cytherea.
Ditrupa plana, *Sow.* sp.
Fusus.
Modiola elegans, *Sow.*
Natica glaucinoides?, *Sow.*
Panopæa intermedia, *Sow.*
Pecten.
Pectunculus Plumsteadiensis, *Sow.*
Pleurotoma.
Tellina.
Teeth of Lamnæ.

In the midst of the chalk district and nearly ten miles to the north of the main body of the tertiaries, I have met with a well-characterized outlier of the basement bed, underlying a capping of London clay, forming the high hill at Lane End four miles west of Wycombe. I found the fossils in blocks of very ferruginous septaria in some small shallow pits on Lane End Common. They were in the state of casts and impressions, and were extremely abundant in some places. They consist of the following species:—

Cardium nitens, *Sow.*
——, n. sp. *a.*
Cytherea obliqua, *Desh.*
Calyptræa trochiformis, *Lamk.*
Fusus.
Modiola elegans? *Sow.*
Natica glaucinoides, *Sow.*
Pectunculus Plumsteadiensis, *Sow.*
Teeth of Lamnæ.

No good section is exposed.

Another small but interesting outlier occurs on the chalk at Tilers' Hill, one and a half mile east of Chesham. Several brick-pits are worked on the summit of this hill, exhibiting in a series of clear sections the several beds from the chalk to the London clay, which here consists of a brown clay with large septaria. At the base of the London clay is a layer of one to two feet of rounded flint pebbles in sand and clay. To this succeeds a series of sands, with some pebble beds, reposing on the chalk. (The section of this hill will be

* Trans. Geol. Soc. 2nd Ser. vol. i. p. 52.

given in a future paper.) The organic remains found here during a very short visit were as under:—

Cytherea obliqua? *Desh.* — Teeth of Lamnæ.
Natica glaucinoides? *Sow.*

Returning to the main line of outcrop, we reach, about midway between Maidenhead and Uxbridge, the small village of Hedgerley, immediately to the south-west of which, in a brick-field on the slope of the hill, is a very interesting section first visited by Mr. Morris and myself in 1842, at which time the section was much clearer than I found it last autumn. The abundance and fine state of preservation of the organic remains at this place far surpass anything that we had then, or that I have since, seen in any part of the tertiaries westward of London, excepting perhaps Sonning Hill. The fossils are preserved in large tabular masses of calcareous clayey green sand containing a few rounded flint pebbles, at the base of the London clay, and immediately overlying the mottled clays. (See fig. 13.)

Fig. 13.—*Section at Hedgerley.*

a. Mixed gravel and clay.

b. London clay: 1. brown and bluish clay with septaria; 2. brownish clay. Fossils scarce in these beds, which attain a thickness of 35 feet at a short distance southward.

c. Blackish clayey sand and green sand, underlaid by flat tabular masses of green sand with a calcareous cement and full of fossils. The small round flint pebbles not numerous.

d. Mottled clays—light greenish grey and red.

The chalk is reached at a depth of 45 feet beneath "*c*."

Organic remains of stratum "c," at Hedgerley.

Cardium nitens, *Sow.*
—— Plumsteadiense, *Sow.*
——, n. sp. *α*.
Cassidaria striata, *Sow.*
Corbula revoluta, *Sow.*
Cytherea obliqua, *Desh.*
—— ovalis, var.? *Sow.*
Ditrupa plana, *Sow.* sp.
Fusus, large finely striated sp.
——, broad smooth sp.
Glycimeris?
Modiola elegans, *Sow.*
Natica glaucinoides, *Sow.*
—— Hantoniensis, *Pilk.*
Nucula.
Ostrea.
Pectunculus Plumsteadiensis, *Sow.*
Panopæa intermedia, *Sow.*
Pleurotoma, large smooth sp.
Pyrula tricostata, *Desh.*
Rostellaria Sowerbyi, *Mant.*
——, n. sp. smaller.
Tellina.
Scalaria.
Vertebræ of fishes.
Teeth of Lamnæ.
Wood in fragments.
A boring Mollusk, probably a Lithodomus.

The concretionary calcareous masses have a brown and weathered appearance, and have been here and there bored into by some mollusk. These blocks are literally full of shells, amongst which the *Cardium* n. sp. *α*, *Cytherea obliqua*, *Natica glaucinoides*, *Nucula*, *Rostellaria Sowerbyi*, and the *Ditrupa plana*, are most abundant. The shells are well-preserved, some with their nacre, but, as at Sunning Hill, their substance is rather soft and friable.

Proceeding by Uxbridge to Watford, occasional imperfect indications of this bed are met with. On the Birmingham Railway, at Bushey near Watford, the mottled clays with the basement bed of the London clay were exposed, in a section which I was too late to see in a good condition. The superposition, however, was sufficiently apparent. The following organic remains were found there by the late Dr. James Mitchell :—

Cardium nitens, *Sow.*
—— Plumsteadiense, *Sow.*
——, n. sp. *α.*
Cytherea ovalis, var.? *Sow.*
Cytherea obliqua, *Desh.*
Nucula.
Panopæa intermedia, *Sow.*
Rostellaria Sowerbyi, *Mant.*

Diverging five miles to the south, the chalk comes so near to the surface in the valley at Pinner near Harrow, that it is worked by shafts sunk through the superincumbent tertiaries. The following is a section of one of these shafts. (See fig. 14.)

Fig. 14.—*Section at Pinner.*

The works were not in operation at the time I visited this spot, and I was unable to procure any of the fossils said to occur abundantly in the stratum which I have marked "*c.* 1."

Passing eastward by Shenley Hill, no good section of this bed occurs until we reach a brick-field one mile east-south-east of Hatfield, and immediately adjoining the east side of Lord Salisbury's park. This pit exposes a complete section from the lower part of

the London clay to the chalk. It may, with fig. 14, serve to show the general relative position of stratum "*c*" to the chalk, but exhibits neither the thickness nor the variety usual in this lower series. (See fig. 15.)

Fig. 15.—*Section near Hatfield.*

a. Gravel—roughly-rounded flint, white quartz, and other pebbles, in nearly white sand.

b. London clay; a very dark grey and brown clay passing downwards into a yellow sandy clay.

c. Sandy brown clay, mixed in its lower part with a few round flint pebbles. Organic remains not numerous. (The division between "*b*" and "*c*" is not well marked, and should probably be placed lower.)

d. 1. A series of thick beds of light yellow and ash-coloured sands, mixed in places with clay. 2. Coarse green sand and clay, full of large, partly rolled, green-coated flints.

f. Chalk.

The only fossils I could here determine were an *Astarte* much resembling the species common at Herne Bay, *Ostrea*, and teeth of *Lamnæ*. Fragments and traces of other shells requiring further examination are met with. Thence by Essenden* to Hertford no sections of this bed are exposed. The next one is in a brick-field on George's Farm, one mile south-east from Hertford on the London road. (See fig. 16.)

Fig. 16.—*Section near Hertford.*

a. Brown clay mixed with flint gravel.

b. London clay; grey and yellow clay passing downwards into dark grey sandy clay. Casts of shells in clay and pieces of soft brown wood not uncommon. The lower part of this probably belongs to "*c*."

c. Round flint pebbles in brown clay, with a few teeth of *Lamnæ*. 4 to 8 inches.

d. Light greenish sand, with traces of mottled red clay, passing down into light ash-coloured sand.

The chalk outcrops at a depth of about thirty to forty feet below "*c*." The organic remains here found in the lower part of "*b*" and in "*c*" are not numerous, and are badly preserved in the form of soft clay casts. Sufficient, however, of them remains to determine with but little doubt the undermentioned species:—

* In a well dug here, I am informed that a mass of shells ten feet thick occurred immediately below the London clay, at a depth of 100 feet.

Panopæa intermedia, *Sow.*
Pectunculus Plumsteadiensis, *Sow.*
Cardium, n. sp. ∝ ?
Astarte?
Fusus.
Ostrea.
Teeth of Lamnæ.

We now enter upon a tract of country, which is so thickly and uniformly covered by beds of gravel and boulder clay drift, that it is rarely that the smallest section of the tertiary beds is visible. Occasionally where the chalk is worked we find a small capping of the sands and mottled clays immediately overlying it; but taking the line of country by Stanstead, Bishop Stortford, Easton near Dunmow, to Great Yeldham, I have not been able to find a single section of the basement bed of the London clay.

Between Yeldham and Sudbury in Suffolk, however, in a brick-field on the brow of the hill near the village of Gestingthorpe, there is a small section in which the basement bed of the London clay may, I think, be identified, although the only fossils I could find in it were the teeth of the usual species of *Lamna*. (See fig. 17.)

Fig. 17.—*Section at Gestingthorpe**.

a. Boulder clay drift.

b. London clay; upper part of brown sandy clay, with the common bluish facets, and containing a few small sandy ochreous concretions; passes down into yellowish sand laminated with greyish clay. No organic remains yet found.

c. Round flint pebbles in sand and clay. Teeth of *Lamnæ* common. No other fossils.

d. Bright yellow sands.

The chalk outcrops near the base of the hill at a depth probably not exceeding sixty to eighty feet beneath "*e*." Continuing over the same irregular hilly district, intersected by narrow and small river-valleys, we pass by Sudbury and Layland to Hadleigh. On a hill one mile E.N.E. of this town, the lower beds of the London clay are worked together with the underlying sands. (See fig. 18.)

Fig. 18.—*Section near Hadleigh.*

a. Mixed clay and gravel.

b. London clay; brown clay passing downwards into a dark grey sandy clay, with a few shells and teeth of *Lamnæ*.

c. Round flint pebbles in sand and clay, with teeth of *Lamnæ*.

d. Light-coloured sands.

The chalk crops out at a short distance below this pit.

* This section, with two near Hadleigh, and three or four near Ipswich, require further examination.

The next section is at Whitton Street, two and a half miles north-west of Ipswich. In some fields to the westward of the high road there are two pits, one of which exhibits the following section. (See fig. 19.)

Fig. 19.—*Section near Ipswich.*

a. Mixed clay and gravel.

b. London clay; brown and occasionally light bluish-grey clay, with a few small ferruginous concretions, passing down into slightly micaceous brown clay laminated with ochreous and yellow sand. No fossils.

c. Round flint pebbles—1 to 10 inches in diameter—in ochreous sand and brown clay. Teeth of *Lamnæ* not uncommon. No other fossils.

d. Light ash-coloured sand, with a few small clayey concretions. No fossils.

The chalk is not here reached, but it crops out at a short distance lower down the hill, and at a level of not exceeding thirty to forty feet below stratum "*c*." There are some pits adjoining Ipswich near the Woodbridge road which exhibit sections of the London clay overlying sands which I believe to belong to the lower Eocene series. I have not examined these pits in detail.

Passing on to Woodbridge, we arrive, at a distance of one mile south from this town, and on the banks of the river, at the Kyson brick-field, a spot well known by the circumstance of the teeth of the Monkey having been found there*. The exact position of the bed in which these remains occur has been considered rather problematical, but I have little doubt that it belongs to the basement bed of the London clay†. (See fig. 20.)

Fig. 20.—*Section at Kyson*‡.

b. London clay. Above this clay, and a little higher on the slope of the hill, the red crag crops out.

c. Round flint pebbles in yellow sand. Teeth of *Lamnæ* common; those of a species of Monkey rare. This crops out on the level of the river.

d. Light-coloured sands; depth unknown. Large *Ostreæ* said to occur in some concretions in the upper part of this bed.

* Owen, Annals Nat. Hist. vol. iv. p. 191.

† It has been already assigned by several geologists to the beds beneath the London clay.

‡ I cannot quite depend upon this section, as I have mislaid my original notes of it.

Organic remains of stratum "c," at Kyson.*

Macacus eocænus, *Owen.*
Didelphys? Colchesteri, *Charlesworth.*
Hyracotherium cuniculus, *Owen.*
Cheiroptera.
Teeth of Lamnæ.

I have found slight traces of fossils in the clay bed "*b*," but they were too imperfect for determination.

A larger section of the London clay is worked near Melton Street, two miles north-east of Woodbridge.

Beyond Woodbridge to the coast the Eocene strata are continuously overlaid by the Crag, and sections of them become still less frequent. On the coast the cliffs at Bawdsley show a section of red crag reposing on the London clay, but these cliffs are not continued to that point (probably not far northward) where the beds below the London clay would crop out.

We have now traced this basement bed of the London clay at intervals in a belt wrapping round the tertiary series for the length of 250 miles.

In the central portions of the tertiary district, the base of the London clay, although not exposed, is reached in many well-sections. Everywhere the same leading features as we have shown to exist at the outcrop, present themselves at greater depths.

The organic remains found in this stratum, unlike those of the London clay, which so generally exhibit internally some form of pyritical or calcareous infiltration giving the fossil a solid form, are usually extremely friable, and have rarely undergone any mineral substitution. The ordinary material of the rock passes into the interior of the shell. The shell itself is almost always preserved, although in a very earthy and friable condition. Still, where care is taken, or when they are imbedded in calcareous masses, they can be obtained in a very perfect state.

Owing to the persistent range of this bed and its distinctive character, I have, to give it a definite designation for the convenience of reference, termed it "the basement bed of the London clay," although viewing it always merely as a subordinate member of the London clay.

Conclusion.

The preceding descriptions I believe embrace, with two or three exceptions, all the principal sections exhibiting the superposition of the basement bed of the London clay. Although, considering the extent of the line of outcrop, they are not very numerous, the intervals between them are sufficiently short to trace this deposit from place to place with considerable certainty. The details of each may vary

* These fossils are as rare as they are curious. They have been found chiefly by the careful and minute search instituted by Mr. Colchester, who, I believe, had the sands and pebbles ("*c*") frequently sifted and examined on purpose. A like close examination might possibly bring to light similar fossils at other localities, especially at those where the structure so nearly resembles that at Kyson (as in figs. 17, 18, & 19). So scarce are these fossils, that in the short visits I have paid to all these pits (Kyson included), I have never found anything but the teeth of the *Lamna*.

in a few points, but they all present a general resemblance. This may not however be considered sufficient for our object—such thin and ordinary beds might be subordinate to some other portion of the Eocene series, and not peculiar to this part of them, and therefore some other proofs of their position may be thought necessary.

In the first place, all the sections in the tertiary district show, by evidence of the clearest kind, that the London clay forms a nearly homogeneous mass, several hundred feet thick, of tough clay of a predominating brown colour—that throughout its whole body it nowhere presents any subordinate beds of a mineral character essentially different from that of its ordinary argillaceous type—and that its organic remains are very irregularly dispersed, abounding in some parts and being entirely wanting in others. This clay occupies an area which is very well defined. Now wherever, without a single exception that I am aware of, the lower beds of this clay outcrop, there is found underlying them a basement bed of a conglomerate character and with or without organic remains—and these, if present, invariably belong to one and the same group of fossils. Further, if we go more into the chalk district, we shall find that whenever the outliers of the lower tertiary sands and mottled clays without organic remains, attain a thickness on an average of from 50 to 100 feet, the basement bed of the London clay invariably sets in. Again, this deposit always exhibits a peculiar mineral character, the chief feature of which is the presence of rounded flint pebbles, mixed with yellow, green, or ferruginous sands in variable proportions. Intermingled with the conglomerate bed, or in the thin sandy layer above it, are frequently found numerous organic remains belonging to a fauna of about forty species, many of which are persistent throughout the greater part of the range of this stratum. Now although the London clay does not always contain organic remains, nor is the basement bed always fossiliferous, neither is the mineral character of one or the other always exactly alike, nevertheless the concurrent testimony afforded in each case, either by position, or by organic remains, or by lithological structure, although the force and value of one or the other class of evidence may vary materially, is I consider, in all the instances I have adduced, sufficiently strong to prove the position assumed. I cannot admit, as has been urged, that the absence of organic remains in the lower beds of the London clay, at New Cross, Upnor, Gestingthorpe, Kyson, and elsewhere (see Sections 8, 10, 17, 20), is an argument against such beds forming part of the London clay. It is not possible to take up a position upon a mere negative fact—to use as substantive evidence that which of itself is but a difficulty arising from variable, and not from conflicting, conditions.

If the "*massif*" of the adjoining district consists of London clay, and the dip and position of the strata, as well as their mineral characters, lead us to suppose that these beds crop out in the position which should be occupied by the lower beds of the London clay, then I hold that as such they must be considered, unless they can be proved to be something else. Otherwise, in trying to avoid one difficulty a more formidable one will be raised, in having

to reduce into harmony with the phænomena of the surrounding district that, which in this case would become an exceptional phænomenon. We should rather seek, by an inquiry into the conditions regulating the distribution of organic remains in the London clay, whether a sufficient reason can be assigned for the absence of organic remains in these portions of the London clay, and to discover how far the phænomenon is a local or a general one.

In Hampshire and the western part of the London tertiary district, the organic remains of the London clay are dispersed with tolerable regularity throughout the whole of its mass, whereas eastward of London the lower beds of the London clay contain, as a general rule, few or no fossils. The fact therefore of the scarcity of organic remains in the lowest clay beds of the London clay in a large portion of its range is a prevailing and not an exceptional feature. It is not alone apparent in those sections where we find only a small extent of the London clay exposed, and on which consequently doubts have been thrown, but also in those sections where we have the successive beds of the London clay exposed from its base up to its well-characterized central beds. Thus in the extensive section in the cliffs adjoining Herne Bay, the base of the London clay is almost, or entirely destitute of fossils, whereas as we reach the beds higher in the series, which are seen gradually setting in, the well-known fossils of this formation become far from scarce. So also at Guildford the lower beds are unfossiliferous, but in proceeding along the dip of the beds towards Woking, organic remains become tolerably abundant.

I have in a previous paper* argued the probability of the London clay of Hampshire having been deposited during a period of a nearly constant, regular, and tranquil subsidence of the bed of the sea, whereby a nearly uniform condition of the sea-bottom, favourable to the prolonged existence of the same group of testacea, was maintained. I also concluded that the subsidence had been greater to the north-east than to the south-west of the Tertiary district, and it therefore follows that it must have been more rapid in the former direction either throughout the whole, or else during particular intervals, of the London clay period; and consequently if the rate of that subsidence was at any time more rapid than the silting up of the sea-bottom, it would result that at such times the sea would become deeper in the north-east than the south-west. Under these conditions we might expect a distribution of the fauna in the north-east of the tertiary district different to that prevailing in the south-west. Now, if the accumulation of the lower part of the great mass of clay forming the London clay commenced during a sudden or even a tolerably rapid subsidence of the sea-bottom in the north-eastern portions of the tertiary area, then the shallow sea fauna of the basement bed could not under these altered conditions of increased depth have been tranquilly transmitted upwards as in the Hampshire area, but must for a time have ceased to live in districts so affected, and, before a deeper sea fauna were introduced, strata might have been deposited with few or no organic remains.

* Quart. Journ. Geol. Soc. vol. iii. p. 354.

After a time, however, the inhabitants of deeper waters would gradually immigrate into these parts of greater depths, and there remain, until from some cause the sea became again sufficiently shallow to allow of the incoming of shallow sea testacea, and then that original fauna, which in the interval had been preserved in the same sea, in the distant Hampshire tertiary area, might have extended itself and reappeared in that part of it spreading over the more central and easterly parts of the London tertiary district.

This I consider to have been the succession of events at this period of the tertiary epoch. On this supposition I account for the absence or extreme scarcity of organic remains in the lower part of the London clay in the central and eastern divisions of the district, and for their abundance in the western divisions. In the neighbourhood of London, as we ascend in this formation, we meet with remains of Cephalopodous testacea in strata succeeding the lower unfossiliferous beds, and we find them further eastward with the remains of Cephalopoda, of Echinodermata, and of other denizens of deeper seas, in some abundance. The lower beds of the London clay overlying its basement bed, may therefore from this cause without difficulty be conceived to present, although synchronous, considerable modifications in their organic remains, whose presence or absence taken separately does not consequently afford a test in this case to the determination of the geological horizon.

We now have to consider the physical changes indicated by the structure of the basement bed itself, marking as it does the passage from the arenaceous beds below to the argillaceous ones above it. Of the conditions of the sea preceding this period we shall treat on a future occasion.

Indiscriminately over all the variable "Lower Eocene" deposits spreads the basement bed of the London clay. It is the first brush of uniformity, where previously all had been different. Extending from the Isle of Wight to Woodbridge in Suffolk, this bed presents some general characters of remarkable persistence. In the first place it is evident that it does not form a sequence in structure conformable to the beds which it immediately overlies. Yet no fresh element is introduced at first into its composition. Although the materials composing this bed are not in many cases found in any of the beds immediately below, yet they all exist in the underlying series in some part of their range, and are, I believe, derived from that source. The great depositary of the rounded flint pebbles in the underlying beds, are the estuary and fluviatile strata of Woolwich and Bromley, where they occur in remarkable abundance. Associated with these pebble beds are thick beds of yellow sand and also several subordinate beds of a strong coarse green sand (which become, however, much more important in East Kent), some beds of a deep ferruginous character, and a few clay beds—the mottled clays of the western districts also are interstratified with beds of yellow sands, but without pebbles. Now the pebbles of the basement bed of the London clay have been probably derived from those previously accumulated locally in these underlying beds, and, if the pebbles, then also

the various sorts of sand associated with those beds, were also likely to have been thus derived. I hold this opinion because this basement bed does not present these different substances in separate and sedimentary order—the bed is composite, and its materials derived, not by a river action bringing down sediment into the sea, but, if I may so term it, by apparently a scouring and general sea action on the pre-existing and underlying beds. That the pebbles in this bed are not in the position in which they received their present form, is, I think, evident from the excessive and lengthened attrition which the flints must have undergone to have formed pebbles of such uniform roundness and finish—a state of things incompatible with the co-existence and preservation of the remains of a delicate and abundant fauna in the same stratum. But we have other and independent proofs of this bed having originated in the destruction of part of the underlying beds. Thus in Section, fig. 1, at White Cliff Bay, it has been shown that rough pebbles of red clay, derived from the harder parts of the underlying mottled clays, occur in this bed; and in Section, fig. 11, at Herne Bay cliff, I have found in this bed specimens of the peculiar uncouth green-coated flints, which form the characteristic bed, reposing almost everywhere in this country and in the North of France immediately on the chalk. These half-rolled green-coated flints have an appearance so perfectly distinct and constant, that their origin cannot for a moment be doubted. Therefore it is probable that the denuding action acted not only on the mottled clays and the pebble beds forming the upper part of the underlying series, but that it in places extended to the chalk itself. It is doubtful however whether the latter suffered much denudation at this time. There are but few traces of its direct debris in this bed. The pebbles of flint I suppose to have been derived from a long-continued wearing away of the chalk at a previous period. The disturbance at the period of the basement bed of the London clay does not appear to have acted with sufficient power on the chalk, nor during sufficient time on the flints, to have produced a large destruction of the former, or to have reduced the latter to the state of such well-rounded flint pebbles.

The irregular and worn upper surface of the lower beds of sands and mottled clays, upon which the basement bed of the London clay reposes, is a corroborative proof of their partial denudation prior to the deposition of the latter. The erosion is certainly not very great, yet it forms an extremely well-marked phænomenon, as at Sonning Hill and Guildford (see Sections 6 and 12), at which latter place it has removed all but a few patches of the Woolwich beds. In the western parts of the London tertiary district it has worn to some extent into the mottled clays.

That the setting-in of this denuding action was sudden, is evident from the abruptness of the change; of its force, the size of the transported pebbles, and the amount of erosion, lead us to judge that it was moderate; and that it was not of long duration is evidenced by the thinness of the deposit.

The erosion is more apparent, and the exhibition of transporting force greater, on the southern flank of the tertiary beds than on the

northern. It was at this period that the great break appears to have taken place between the English and French tertiaries; for up to this point, the sands, mottled clays, and fluviatile beds are common to both countries, and present much similarity of structure. But at this level the resemblance ceases; the London clay sets in with its great argillaceous character, whilst in France this period is succeeded by a series of light-coloured, calcareous, and generally very fossiliferous sands and earthy limestones. I do not think this separation of the two districts to have been caused by the elevation of the Wealden: in the first place, because the London clay is found in nearly equal force on both sides of the Wealden elevation; and in the second place, because there is evidence (see Sections 4, 5, and 6) that that elevation affected these Eocene strata equally with the secondary ones. It would appear therefore, on physical grounds, that the denudation acted from the southward, while it has been before shown, on palæontological evidence, that in this same direction there was probably a considerable rise of the sea-bottom, accompanied by a slight subsidence to the northward. To the disturbing action of the waters flowing off from the sea-bottom thus raised to the southward, I attribute the first spread of the basement bed of the London clay and the partial denudation of the underlying strata. The elevation of the bed of the sea was not sufficient to convert it into dry land, nor was the change of that violence to destroy, over the whole area acted upon, the animal life of the period. In distant or in more sheltered parts of the sea, as before mentioned, some of the testacea which inhabited it were preserved and transmitted into the deposits formed subsequently to these changes.

The basement bed of the London clay contains altogether thirty-one known species of testacea, and apparently eight to ten undescribed species. In Hampshire and in the western division of the London district there are in the underlying strata no remaining traces of any older stock whence this new fauna could have been derived. From London, however, through Woolwich to Upnor, this bed reposes upon fossiliferous fluviatile beds, and here apparently there seems to be a transmission upwards, from one period to another, of some of the species, as the *Cyrena obovata*, *C. cuneiformis*, *C. tellinella*, *Cerithium variabile*, *Melania inquinata*, and *Pectunculus Plumsteadiensis*, which abound in the estuary and fluviatile beds of Woolwich*. Some of the species also from the lower marine deposits of Herne Bay and Sandwich range upwards into the "basement bed," as the *Corbula revoluta*, *C. longirostris*, *Natica glaucinoides*, and *Pectunculus Plumsteadiensis*, and probably the *Cyprina Morrisii*. There is this difference, however, between the species introduced from the underlying beds, and those which constitute the typical and universal group which will shortly be alluded to, viz. that the former are, with the exception possibly of the *Cyprina Morrisii*, confined in their range to a limited region, surmounting or not extending much beyond (*i. e.* at this period) that previously occupied by them, whilst the latter have a general and unlimited range.

* Out of these six species four even lived on to the period of the freshwater series of the Isle of Wight.

northern. It was at this period that the great break appears to have taken place between the English and French tertiaries; for up to this point, the sands, mottled clays, and fluviatile beds are common to both countries, and present much similarity of structure. But at this level the resemblance ceases; the London clay sets in with its great argillaceous character, whilst in France this period is succeeded by a series of light-coloured, calcareous, and generally very fossiliferous sands and earthy limestones. I do not think this separation of the two districts to have been caused by the elevation of the Wealden: in the first place, because the London clay is found in nearly equal force on both sides of the Wealden elevation; and in the second place, because there is evidence (see Sections 4, 5, and 6) that that elevation affected these Eocene strata equally with the secondary ones. It would appear therefore, on physical grounds, that the denudation acted from the southward, while it has been before shown, on palæontological evidence, that in this same direction there was probably a considerable rise of the sea-bottom, accompanied by a slight subsidence to the northward. To the disturbing action of the waters flowing off from the sea-bottom thus raised to the southward, I attribute the first spread of the basement bed of the London clay and the partial denudation of the underlying strata. The elevation of the bed of the sea was not sufficient to convert it into dry land, nor was the change of that violence to destroy, over the whole area acted upon, the animal life of the period. In distant or in more sheltered parts of the sea, as before mentioned, some of the testacea which inhabited it were preserved and transmitted into the deposits formed subsequently to these changes.

The basement bed of the London clay contains altogether thirty-one known species of testacea, and apparently eight to ten undescribed species. In Hampshire and in the western division of the London district there are in the underlying strata no remaining traces of any older stock whence this new fauna could have been derived. From London, however, through Woolwich to Upnor, this bed reposes upon fossiliferous fluviatile beds, and here apparently there seems to be a transmission upwards, from one period to another, of some of the species, as the *Cyrena obovata*, *C. cuneiformis*, *C. tellinella*, *Cerithium variabile*, *Melania inquinata*, and *Pectunculus Plumsteadiensis*, which abound in the estuary and fluviatile beds of Woolwich*. Some of the species also from the lower marine deposits of Herne Bay and Sandwich range upwards into the "basement bed," as the *Corbula revoluta*, *C. longirostris*, *Natica glaucinoides*, and *Pectunculus Plumsteadiensis*, and probably the *Cyprina Morrisii*. There is this difference, however, between the species introduced from the underlying beds, and those which constitute the typical and universal group which will shortly be alluded to, viz. that the former are, with the exception possibly of the *Cyprina Morrisii*, confined in their range to a limited region, surmounting or not extending much beyond (*i. e.* at this period) that previously occupied by them, whilst the latter have a general and unlimited range.

* Out of these six species four even lived on to the period of the freshwater series of the Isle of Wight.

TABLE A.—Showing the general range and hire and

Note.—The line of range is taken from the Isle of Wight no at their relative geographical distances. Where there are breaks in of the species at any given place. The last two columns show the

		White Cliff Bay, Isle of Wight.	[illegible] it (marked O),	Found in the beds underlying the Basement bed of the London Clay.
Conchifera.	Ditrupa plana, *Sow.* sp.			
	Panopæa intermedia, *Sow.*			
	Corbula revoluta, *Sow.*			*
	—— longirostris, *Desh.*			*
	Cyrena cuneiformis, *Sow.*			*
	—— obovata, *Sow.*			*
	—— tellinella, *Fer.*			*
	Cyprina Morrisii, *Sow.*			*
	Cytherea obliqua, *Desh.*			*
	—— ovalis, var., *Sow.?*			
	Cardium nitens, *Sow.*			
	—— Plumsteadiense, *Sow.*			
	——, n. sp.			
	Pectunculus brevirostris, *Sow.*			
	—— Plumsteadiensis, *Sow.*			
	Nucula margaritacea, var. B, *Desh.*			*
	Modiola depressa, *Sow.*			*
	—— elegans, *Sow.*			
	Ostrea Bellovacina, *Lam.* (O. pulchra ?)			*
Mollusca.	Calyptræa trochiformis, *Lam.*			
	Melania inquinata, *Def.*			*
	Natica glaucinoides, *Sow.*			*
	—— Hantoniensis, *Pilk.*			
	—— labellata, *Lam.*			
	Cerithium variabile, *Desh.*			*
	Cancellaria læviuscula, *Desh.*			
	Rostellaria Sowerbyi, *Mant.*			
	——, n. sp.			
	Cassidaria striata, *Sow.*			
	Buccinum junceum, *Sow.*			
	Fusus tuberosus, *Sow.*			
	——, n. sp.			
	Pyrula tricostata, *Desh.*			
	Pleurotoma comma, *Sow.*			

After deducting the Woolwich and Herne Bay species from the fauna of this period, there remains nineteen out of thirty-one described species which are not found in the underlying deposits. They form a distinct and well-marked group, and the individuals of the species are often extremely numerous. The principal species are the *Panopæa intermedia*, *Cytherea obliqua*, *C. ovalis*, var.?, *Cardium nitens*, *C. Plumsteadiense*, *Pectunculus brevirostris**, *Natica glaucinoides*, *N. Hantoniensis*, and *Rostellaria Sowerbyi*. In the western districts the *Ditrupa plana* is also particularly abundant, and the *Pyrula tricostata* is common, but both these die out or become very scarce as they range eastward.

Between the eastern and western districts there is also a space (including Woolwich, Upnor, Boughton) where, owing probably to the more brackish state of the sea, as evidenced by the great and sudden abundance of *Melania* and the several species of *Cyrena*, many other marine genera disappear. A few, as the *Panopæa*, *Rostellaria*, one species of *Cardium*, and *Calyptræa*, are however persistent throughout (see Table A.). Notwithstanding this interruption, the fauna at Herne Bay presents a remarkable similarity to that which flourished at the same period at Hedgerley, Reading, and Clarendon Hill, modified only by the introduction of the few shells before mentioned.

It is to be observed, however, that the fossils of this deposit, although they have so persistent a range from west to east, decrease rapidly to the north-east, and from their nearly total absence in Essex and Suffolk, an argument might be brought against the identity which I have there given to that deposit in Sections Nos. 17 to 20. On structural and lithological grounds I have before argued in favour of this identity, and I cannot view this absence of fossils as a militating argument of much weight against such a supposition. If it occurred on a line where the same bed in adjacent sections was very fossiliferous, then the question would be attended with some difficulty; but in this instance we are led almost naturally to anticipate their disappearance, from their rapid decrease as we proceed eastward on their northern line of outcrop from Hedgerley, where they abound, by Watford, where they are far less numerous, to Hatfield and Hertford, where they are comparatively scarce. Their decrease in this direction is in that ratio, that their rarity or absence in Essex and Suffolk presents no anomaly. The only fossil constantly present is the tooth of a species of *Lamna*, probably the *Lamna elegans* of Agassiz.

In order better to show the range of the organic remains of this bed, I have added the accompanying Table A. with a list of all the described species and of two or three of the more important undescribed ones. As a group, it will be observed that these species are essentially those which we find afterwards characterizing the London clay, and that the other species, which range from the beds below, are fewer in numbers, and possess usually a very wide vertical, although at this level they exhibit a very limited horizontal, range†.

* I do not give the *Pectunculus Plumsteadiensis*, as it seems to me to be doubtful whether this species is not a variety of the *P. brevirostris*.

† The breaks in the range of many of the species will probably decrease as the examination of this bed is made more complete at some of the localities.

With regard to the condition of the sea immediately anterior to the period of the deposition of the basement bed of the London clay, it is probable that the whole, or nearly so, of the south-east of England was occupied by the Eocene sea, studded with a few islands. An important one may have existed at some point between Woolwich and Newhaven (unconnected however with the elevation of the Wealden as it has since taken place). On the shores of these islands small rivers accumulated fluviatile and estuary deposits, such as those of Woolwich, New Cross, Upnor, and Newhaven, whilst further eastward marine deposits were accumulating in the open sea stretching to, and probably beyond, the now Isle of Thanet.

In this state of things a movement of depression probably took place over this district in a direction W.S.W. to E.N.E. from Hampshire to Suffolk, whilst a corresponding and coæval elevation took place perhaps on a parallel line further south, and passing, I am rather inclined to believe, south of the Isle of Wight towards the north of France, and not touching upon the area now occupied by England. From off this raised sea-bed to the south, a wave of translation (if the term may be applied to deposits of this period), of moderate power and having a N.N.W. flow, would be thrown, spreading over the bottom of the sea, debris derived chiefly from the older eocene sands and pebble beds forming the bed of the sea over which this wave moved. This wave would decrease in force as it receded from the axis of elevation, whence the diminished erosion of the surface, and the generally smaller size of the pebbles, in Essex and Suffolk. The spread of this debris would afterwards be further modified and extended by currents. At the same time, the sea, then of moderate and tolerably uniform depth, was extended over a larger area than it before occupied. The ancient river-courses were altered, their deposits ceased wholly or partially, and no new rivers yet came into full operation, for the fauna lived and flourished on a sea bed which evidently received but little addition of sediment during this period. Over the eastern part of Kent, however, the actions of currents and perhaps of small rivers still led to the accumulation of deposits of fine sands, increasing in thickness from two to three feet near London to twenty feet at Herne Bay.

Westward of London in no case does the basement bed of the London clay present a thickness of more than five feet, and in many places it does not exceed one foot. Where the passage from this stratum to the mass of the overlying London clay is gradual (see Sections 1, 5, & 12), fossils usually abound, especially near the line of junction; while if the argillaceous beds repose at once on a compact and separate layer of pebbles, few or no fossils are found (see Sections 3, 7, 8, 17).

This profusion in some localities of organic remains, and their dispersion over so wide an area, render it also probable that, after the first spread of the debris of pebbles and sand, a considerable interval of time elapsed before the argillaceous beds of the London clay began to accumulate, a process which however afterwards set in gradually and without any mark of further disturbance, the necessary physical changes having taken place at the period of its basement bed. At the same time the occasional presence in this bed of the remains

of a boring mollusk would lead to the supposition that the first change after the interval of repose was one of a slight and tranquil elevation, by which the recently-formed deposit was raised either near to or above the surface of the sea, according to the irregularities of the sea-bottom. On the emerged portions the *Lithodomus* might have lived, and there left traces of its existence, as exhibited in the borings in the calcareous masses of this age at Hedgerley, and in the large and thick oyster-shells of the same date at Maryland Point. The places at which these remains occur, appear to me too detached and isolated to favour the supposition of a continued and extended line of coast.

The slight elevation here alluded to would also, by bringing fresh currents into action, account for the fact before-mentioned of the argillaceous beds of the London clay sometimes passing gradually downwards into this arenaceous and conglomerate bed, and at other times reposing abruptly on a mere layer of pebbles, the latter places having been more exposed to the denuding action of these currents whereby the lighter portions of the deposit might have been removed. This movement I consider to have been but part of a very gradual and comparatively imperceptible oscillation, which, after producing a slight elevation, led to a long-continued subsidence productive of further and important changes in the distribution of land and water of that period. By these mutations new rivers would of necessity be formed, or the old ones would take a new course according as the watershed of the country was shifted, and thus probably originated that powerful fluviatile action, which swept down into this Eocene sea the vast argillaceous sediment, with its rich stores of land plants and marine animals, forming the London clay.

I conclude therefore that the basement bed of the London clay constitutes a well-marked horizon, dividing the London clay formation by a change, both in the palæontological conditions and in the ancient physical geography of the district, from the older Eocene deposits which intervene between the chalk and the London clay, its mineral mass being composed of the debris of the former, while its animal life belongs to the period of the latter.

I hope to treat of the remaining division of this series at a future period.

FEBRUARY 6, 1850.

W. Pengelly, Esq., and Lieut.-Col. J. A. Lloyd, were elected Fellows.

The following communication was read:—

On the EARLIER VOLCANIC ROCKS *of the* PAPAL STATES, *and the adjacent parts of* ITALY. By Sir RODERICK IMPEY MURCHISON, G.C. St. S., V.P.G.S. &c. &c.

Introduction.—During a winter's residence in Rome, including

journeys to and from that city by the Maremma, Siena, and Viterbo on the west, and by Perugia on the east, together with excursions, including one to Naples, in the spring, the abundant "earlier volcanic" products of that region were necessarily brought under my notice. For, although my chief object in visiting the peninsula was to ascertain the order of succession from its secondary to its tertiary strata, the very existence of those formations, particularly of the latter, was so intimately connected with contemporaneous or subsequent eruptions of volcanic matter, that it was impossible for any geologist not to be alive to the importance of observations which tended to throw light on the conditions under which such igneous operations took place. I had moreover a strong additional motive to enter into this branch of our subject, from habitual intercourse with my friend, the accomplished mineralogist, Count L. Medici Spada*, and his zoological coadjutor Professor Ponzi.

Although all the materials prepared by these authors will, I trust, at no distant day be published†, still as they will even then appear in a foreign language, and will imbody local phænomena not requisite for the clear comprehension of the subject, I venture to offer the present sketch, which, although in part derived from the labours of my above-mentioned friends, contains a modification of their views concerning the Latian Hills, which I consider to be of some importance‡.

Not entering fully into the details of the literature of this subject, I may briefly observe, that, among the writers who have treated of the subsoil of Rome, Brocchi was the first modern who gave it a specific geological character. Whatever errors his work, entitled 'Suolo di Roma,' may have contained, have been corrected to a great extent by Leopold von Buch, Lyell, Hoffman, Pareto, and other authors. Still, looking at the only geological map of Italy yet published, the value of the distinction which is advocated in this memoir will at once be seen. For in that very useful map, the author, M. Collegno, has not attempted to separate the oldest trachytes and basalts, associated with the subapennine strata and obviously of subaqueous origin, from modern volcanos; so that the Euganean Hills and

* At that time Monsignore Medici Spada.

† Monsignore Medici Spada was preparing for my use a descriptive memoir in Italian, which it was my intention to have had translated into English, when the political agitation to which Rome became subject suppressed every spark of scientific energy. Still, before I left that city, I was fortunate enough to induce Professor Ponzi to lay aside his military uniform and accompany me over the Latian volcanos, of which he prepared an instructive map, of which the diagram, fig. 3, p. 285, is a reduction, accompanied by sections.

‡ Since these pages were written, Professor Ponzi has published a memoir, entitled "Osservazioni Geologiche lungo la Valle Latina," Roma, 1849, in which he shows the existence of volcanic rocks, of the same age as those of Hannibal's Camp, at Tichiena and Posi, near Frosinone. I cannot agree with my friend, when he places the Macigno between the hippurite limestone and the nummulite rocks, nor do I admit that there is any geological distinction between the cretaceous limestone of the Volscian Hills and that of the Sabine Hills. (See my former Section, Quart. Jour. Geol. Soc. vol. v. p. 281, fig. 35.)

Radicofani are represented under the same colours as Etna and Vesuvius.

Tracts north of Rome.—No geologist can travel from Radicofani to Rome, nor examine the Campagna di Roma, properly so called, in any direction, without being satisfied that the region is eminently one of volcanic character. He sees around him numerous crateriform cavities, evincing the former action of fire; but when he more closely examines them, he has little difficulty in perceiving, that although volcanic in a general sense, they are distinct from the craters of Central France, for example, or of any other region in which atmospheric or subaërial volcanos have operated. In the Campagna there is no trace of the broken-down side of a crater, and still less of any currents of subaërial lava which flowed from such depressions, like those which so decisively demonstrate the origin of the currents or "cheires" of Auvergne. On the contrary, all the stratified accumulations of basaltic rocks, tufa, sand, lapilli, puzzuolana, travertine, or gravel, indicate most clearly that they have all been formed or rolled under *water*. Among the oldest, and at the same time the most crystalline of these rocks, is the basaltiform felspathic greystone with quartz crystals of iolite or prismatic quartz, the tephrine lava of Brongniart, which occupies the rugged hill of Radicofani, about 2470 French feet above the sea, and a few miles only to the east of the higher trachytic mountain of Amiata.

The chief remark I have to make on this rock is, that it seems to have been thrust up through a basin of tertiary subapennine marls, a portion of which it has overflowed and covered, just as many of our Hebridian trap rocks (to use a British illustration) have been protruded through, and have surmounted, our oolitic shales. The Marquis Pareto also describes the tephrine of Radicofani as overlying the tertiary strata; but Pilla believes it is so old, that the subapennine marls were accumulated around it subsequent to its emission. The utter dislocation however of these marls, where they are visible amid the masses of detritus on the slopes of the hills, convinces me, that the igneous rock burst through them at Radicofani, and then overflowed them. There are some appearances as if currents of lava had proceeded from this mountain of Radicofani, but they are soon broken off, and are traceable only in loose dismembered blocks which spread over the slopes, particularly to the south. On descending from the mountain, and after travelling to the opposite bank of the Paglia, we find what I consider to be the same tephrine lava regularly stratified in the escarpment above Ponte Gregoriano, north of Acquapendente, where the Papal States are bounded by Tuscany. The blue subapennine marls, fig. 1 *a*, p. 284, are there well exposed at the base of the cliff, partially covered by a thin coating of yellow sand, fig. 1 *b*, both of them well known in these countries as containing marine shells; and these are immediately and conformably surmounted by an amygdaloid, the concretions of which are as compact and well-filled as any trap-amygdaloid of the Highlands. This is followed by a considerable band of the grey basalt, fig. 1 *c*, or tephrine lava with leucite, on which Acquapendente, like Radicofani,

Fig. 1.—*Section at Acquapendente.*

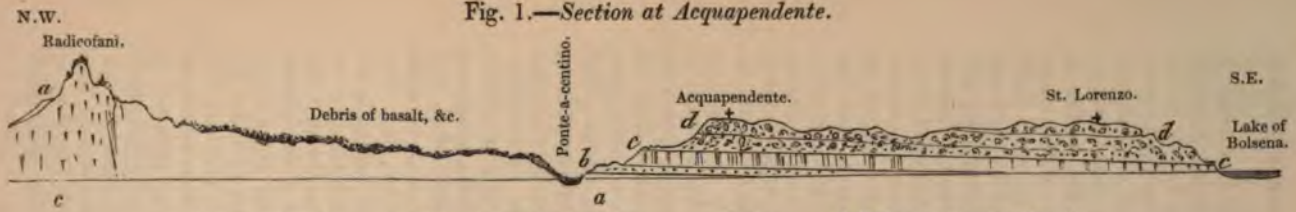
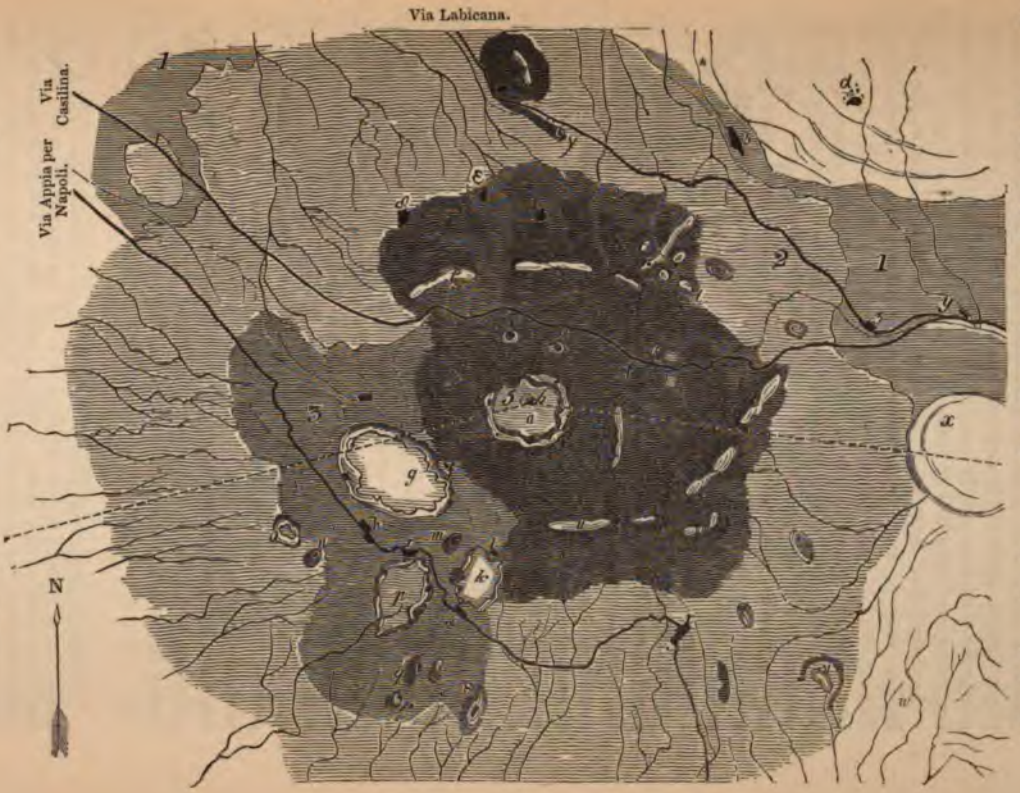


Fig. 4.—*Section of the Latian Hills.*

Fig. 5.—*Transverse Section of Rocca Monfina.*

Fig. 3.—*Map of the Latian Hills.*



a. Hannibal's Camp.
b. Monte del Vescovo.
c. Rocca di Papa.
d. Monte Pila.
e. Monte Cava.
f. Palazzolo.
g. Lago Albano.
h. Albano.
i. Ariccia.
j. Genzano.
k. Lago di Nemi.
l. Nemi.
m. Monte Gentile.
n. Monte Savelli.
o. Lago di Giuturna.
p. Valericcia.
q. Monte delle Torri.
r. Monte Giove.
s. Civita Lavinia.
t. Velletri.
u. Monte Artemisio.
v. Lago della Torre.
w. Giulianello.
x. Monte Fortino and Monti dei Volsci (*Hippurite limestone*).
y. Val Montane.
z. Lugnano.

α. Palestrina and Monti degli Ernici (*Hippurite limestone*).
β. Zagarolo.
γ. Colonna.
δ. Frascati.
ε. Tuscolo.
ζ. Monte Porzio.
η. Monte Compatri.
θ. Rocca Priora.
ι. Monte Algido.
κ. Laghetti.
λ. Siani della Molara.
μ. Castello del Tusculo (*Crater*).
ν. Monte delle Tartarughe (*Crater*).

1. Subapennine strata.
2. Volcanic tuff of the Campagna.
3. Peperino.
4. Volcanic scoriæ, &c.
5. Lacustrine deposits.

is built*. The still higher plateau, south of the town, is occupied by great thicknesses of the well-known yellowish tufa of the Campagna, fig. 1 *d*, in the puzzuolana or sandy beds of which many caverns have been excavated. Now, if the "tephrine lava" had happened to contain zeolite instead of leucite, any British geologist might call it a trappean greenstone; and, as it is, there can be no sort of doubt that these Italian earlier volcanic products are as much of subaqueous origin as the blue shelly marine marl and sands which they have traversed, and which they immediately overlie.

In descending from St. Lorenzo to the Lake of Bolsena, the hard leucite rock is seen to contain crystals of pyroxene, hornblende, felspar, and mica. Occasional fragments of secondary Apennine limestone also occur in this rock, but leucite is the dominant mineral. This leucitic rock is encased in a vast thickness of tufaceous, sandy or marly tufa, in parts a peperino, in parts scoriaceous. It is in this feature of being more scoriaceous, and in here and there having a rough or trachytic aspect, that these eruptive rocks, whether basaltic and compact or loose and scoriaceous, more resemble modern lavas and their accompaniments than our British traps. But I observed nothing like a regular quâ-quâ-versal or outward dip from the Lake of Bolsena. The Marquis Pareto, however, who examined the whole circumference, speaks of a slight outward inclination; but even if it be so, on those sides of the lake which I did not examine, there is little or no analogy between such an arrangement and the highly inclined dejections of a subaërial volcano. Pareto's words are only to this effect: "Questi banchi inchinano generalmente più al di fuori, *che verso il centro* della cavità medesima." The hard, compact leucitic rock, which occurs near the summit of the escarpment at the north end of the lake, is again found very little above its level to the south side of the town of Bolsena, where it ranges in devious columnar masses, not unlike many of our prismatic basalts, and is composed of numerous pentagonal and hexagonal columns, the ends of which vary to different angles with the horizon, depending probably upon the outline of the cooling surfaces of the pre-existing materials with which the eruptive lava came in contact. Further southward, *i. e.* on the east bank of the lake, whitish claystones, in parts having a semi-pumiceous or trass-like aspect, alternate with courses of grey-coloured scoriaceous lava. Few persons, who have examined this country, will, I apprehend, be disposed to doubt, that the trachytes of Tuscany and the Papal States are among the oldest of these earlier volcanic rocks. Of this, in-

* In Brongniart's classification of rocks, the basalt of Radicofani is called "Téphrine pavimenteuse," and is associated both with the lava of Volvic, in Auvergne, and with a production of Monte Nuovo in modern times. And yet nothing can be *geologically* more distinct than the periods of eruption of these three rocks. Again, the basalt under Acquapendente, which geologically, in my opinion, is simply a varied mineral prolongation of a ban d issuing from the same centre as that of Radicofani, is distinguished as "Téphrine amphigénique," merely because it happens to contain imbedded crystals of amphigène or leucite.—*Classification des Roches*, pp. 118–119.

deed, the Marquis Pareto has afforded undoubted proof by his description and sections explanatory of the structure of the tract south of Viterbo*. Monte Soriano, for example, which the traveller to Rome from Viterbo leaves upon his left hand, and which rises to about 3300 feet above the sea, is essentially a mass of trachyte, overlapped by these tuffs and scoriaceous accumulations, which encumber the sides of the road at L' Imposta between Viterbo and Ronciglione. These latter deposits only, according to Pareto, could have had an uninterrupted communication with the atmosphere. The priority of the trachyte, or its formation under different conditions, is, as I shall hereafter show, a point of considerable importance in its bearing on the question of the origin of Rocca Monfina in the Neapolitan States.

* For a more special description of the western part of the volcanic region of the Papal States than is offered in my sketch, I refer the reader to a memoir of the Marchese L. Pareto, entitled "Osservazioni Geologiche dal Monte Amiata à Roma." (Extract from the Giornale Arcadico, Roma, 1844.) This author, by an appeal to natural sections, proves that of the volcanic rocks, as distinguished from plutonic, trachyte is the most ancient, and that at points east and south-east of Viterbo, that rock, resting at once on tertiary marine strata, is covered by pumiceous aggiomerate and volcanic tuff. All the trachytic masses which I have seen in Italy, conveyed to me the idea that they had issued in a pasty state, so as to form domes and flattened cones, which, traversing the pre-existing strata of subaqueous origin, were *the precursors* of all the other volcanic productions of the peninsula. The numerous varieties of trachyte, its crystals of riaccolite, its lithological divisions into fire-stones, paving-stones, &c., and its metamorphic influence on the contiguous deposits, do not come within my present object. (See the works of P. Savi, Pareto, Pilla, &c.) All the subsequent volcanic products of the Papal States are grouped together by Pareto under the heads of tuff with peperino, and lava with lapilli. He believes that all the tuff with peperino and solid agglomerates were formed and arranged under water, whilst the eruption and fall of the lapilli may have occurred at points in connexion with the atmosphere. He gives a full account of the form and structure of the dejections all around the great cavity of the Lake of Bolsena, and is disposed to think, that its parasitic and crateriform depressions, occupied by smaller lakes, may be craters of elevation. Although no one of these cavities—not even the Lago de Vico—seemed to me to fall into the same category as the extinct true volcanos of Auvergne, still I agree with Pareto, that some of the scoriaceous and pumiceous materials, particularly on the plateau south of Viterbo, were probably ejected into the atmosphere. These have, I admit, so subaërial an aspect, that they may well represent the last operation in a series of volcanic eruptions, which terminated as the grounds rose, by throwing up much matter into the atmosphere. Whilst Pareto believes that the depressions near L' Imposta and the Lake of Vico may have been craters whence the leucitic and hornblendic "tephrine" basalts or lavas flowed, he thinks, as I do, that *by far the greater portion of every* volcanic eruption, even in these Colles Ciminii, was subaqueous. In my opinion, such outbursts as that of Graham's Island would explain all, even the most recent, of the volcanic phænomena in the northern Campagna and the region around Viterbo.

The post-pliocene shelly formations on the coast of Civita Vecchia, which are loaded with numerous fragments of the earlier volcanic rocks of which we are treating, show that these last mentioned were consolidated anterior to the accumulations of that ante-historic sea. This evidence tends also to prove, that although, even at that time, so remote in respect to our day, the mollusca living in the sea were the same as those which now inhabit the Mediterranean, the physical geography of the coast of Italy must have been widely different from its present outline; and that as hills, that are now 300 feet above the sea, were then beneath it, so all the lower countries of the Campagna must have been then under water, whether salt, brackish, or fresh. This point will be again adverted to in treating of the Latian volcanos.

But, if for a moment we were inclined to suppose that such rocks as the tuffs of the Campagna might have been formed under the atmosphere, all doubt would be dispelled by finding them associated with, and covered by great thicknesses of water-worn, pebbly detritus. In short, when we follow these dejections from Monte Fiascone to Viterbo and the lakes of Vico, Baccano, and Bracciano, up to Monte Mario and the gates of Rome, we see that their very uppermost dejections are so intimately associated with the upper subapennine strata charged with marine shells and water-worn rounded pebbles of apennine limestone, that all doubt is dispelled, and we are compelled to conclude that all, or nearly all, such earlier volcanic rocks as I have hitherto alluded to, and which occupy the Campagna, were formed either entirely under the sea, or in that condition of things when the former bottoms of seas were emerging and were covered with brackish or impure lacustrine waters. Many of these rocks may be included in the peperino of Brongniart; and although Brocchi attempted to divide them into stony, as distinguished from granular tuffs, and a third variety that may be called earthy tuff, I quite agree with Pareto, that all such divisions depend on mere local accidents and have no sort of geological bearing. All these rocks, however varied, constitute in fact but one formation, from the farinaceous tuff of Monte Verde, near Rome, to the more solid tuffs and leucite lavas of the Ciminian Hills. I have thus dwelt on the true nature of these rocks, in order to attach what I consider to be the right meaning to the words "craters" and "volcanos," which have found their way into the descriptive hand-books of Italy, and which may lead tourists to fancy that there were formerly many volcanos like Vesuvius and Etna in this region of the Papal States.

Of the older class of volcanic rocks I will now cite a few other examples. The deep ravine near Monte Fiascone exposes on its sides fine sections of rocks, the high antiquity of which in relation to the present condition of things is further indicated by their having afforded the materials for those huge rounded blocks of peperino, &c. which are strewed over the slope extending from Monte Fiascone into the sterile valley north of Viterbo, in which the well-known Bulicami, or hot springs, have their issue. All these blocks were manifestly transported by great aqueous currents*.

It is in the sandy varieties of this group of rocks called panchina, puzzuolano, &c., that far the greater number of the Necropolises of the Etruscans were excavated, as well as the crypts and subterranean sanctuaries of the earlier Christian martyrs and refugees in the environs of Rome. He who visits the site of the ancient Etruscan city of Veii may at once verify this observation; for whilst the fortress stood on the harder rocks (leucite lava, &c.), the tombs of the Necropolis were burrowed out of the softer sandy tuff to the north of the city, which is manifestly a finely laminated subaqueous deposit. In the same way at Volterra, where the rocks are not of igneous origin,

* The formation of the great globular concretions of peculiar travertine by these "bulicami" of Viterbo are described in Lyell's 'Principles of Geology,' 7th edit., p. 243.

but are simply the subapennine clays with yellow sands and sandstone, we see how the Etruscans, building their city on the former, constructed their tombs in the dry and easily worked strata of the latter, the "panchina" of the Italians. Tufaceous dejections and erupted rocks containing leucite similar to those already described, occupy large portions of the Papal Maremma. They are also particularly well developed in that undulating low country which constitutes the north-western part of the Campagna and extends from Monterosi by Nepi to Civita Castellana. The cliffs and deep denudations of the last-mentioned place are very striking, and the right bank of the Tiber near Borghetto is instructive in exhibiting the pebble beds of the upper subapennine period surmounted by leucitic lava, thus unquestionably proving, that this igneous rock was poured out under the waters, whilst still lower down in the valley there are re-aggregated heaps of a later aqueous drift, in which leucitic rocks and the debris of pre-existing pebble beds are all mixed up together; a condition of things in all respects analogous to that which I have described as occurring at Ponte Molle near Rome*.

Again, in passing by Eropete and Castelluccio to Otricoli, pebble beds composed of Apennine limestone are seen distinctly to alternate with volcanic tuff. Associated with these subaqueous volcanic dejections of the Papal States, are travertines which have evidently been formed at different periods. Thus, near Siena, the accompaniments of the volcanic phænomenon are almost confined to a copious evolution of travertine, loaded with coarse angular blocks of younger secondary limestone, occasionally two and three feet in diameter, which are honeycombed throughout and associated with tuff, marl, &c. These masses immediately overlie the subapennine marls and sand, and are covered by lacustrine limestone with *Lymneæ* and *Planorbes*; and this again by sandy loam with land remains and coarse alluvia.

Travertine past and present.—The sequence of strata in the southern parts of Tuscany just mentioned, shows very clearly, that the purely marine condition of the strata under which the subapennine sea-shells were accumulated, gave place gradually to other subaqueous conditions, in which, after many "quasi" volcanic eruptions, accompanied or followed by the formation of much travertine, those conditions were at length terminated by a more purely terrestrial state. Evidences in the Campagna di Roma still more completely sustain this view. Spada and Ponzi have, it is true, found fragments of an older travertine in the tuff of this region†, but they admit, that the *chief* masses of travertine (principally formed under water) are of a date posterior to the earlier volcanic rocks I have been describing. In my former communication‡ I exhibited a diagram showing how the lacustrine travertine of Ponte Molle belongs

* See Quart. Journ. Geol. Soc. vol. v. p. 296.

† Savi describes a travertine in the Pitigliana in Tuscany, which is covered by volcanic tuff and peperino. Such cases are, however, exceptional, and Pilla admits that the great masses of ancient travertine are of the younger pliocene age.—*Saggio Comparativo dei terreni*, &c. p. 25.

‡ See Quart. Journ. Geol. Soc. vol. v. p. 296, fig. 40.

to that posterior date, and there can be no doubt, that from the period when the lower grounds were still much under brackish or fresh water, and when travertine was formed in broad ancient depressions then occupied by waters which are now reduced to the rivers Tiber and Anio, there has been a more or less continuous formation of travertine. In order, however, to draw a clear distinction between the former energy of nature in producing travertine under conditions different from those which now prevail, let us appeal to Tivoli and its environs. There we have fortunately exact chronometers. There we can compare the enormous ranges of this calcareous deposit which were elaborated long before man could have trodden the soil, with those small additions which have been made by the river Anio since the foundations of the Etruscan and Roman buildings.

Fig. 2.—*Section at Tivoli.*

All Tibur or Tivoli, with its temples, stands on what may be designated the ancient travertine, fine lofty scarps of which hang in undulating and contorted layers with their splendid concretions on the flanks of the cretaceous or hippuritic limestones of the Sabine Hills, where not a rill of water now descends, and where consequently not an inch of travertine is ever added. He who would convince himself that the great mass of travertine belongs to a remote antiquity when the configuration of the land was very different from the present, has indeed only to ascend by the small old road from the Villa Adriana to Tivoli. He will there see the truncated edges of that finely laminated rock associated with water-worn pebble beds of a former epoch, when these deposits must either have shelved away from eminences which they now occupy, into waters which then bathed the flanks of the Apennines, or when great barriers, since removed, pent up lakes at higher levels. Again, if he should descend from the walls of Tivoli to the ancient Via Tiburtina, he will successively pass over, first some beds of travertine on the summit, next beds of pebbles chiefly of apennine limestone, and thirdly a great mass of travertine. The whole of these repose distinctly on volcanic tuff, with much disseminated leucite, in which caverns have been excavated, and the lower portions of which have been channeled out by the Teverone or Anio (see fig. 2).

The quarries out of which ancient Rome was in a great part built, situated in the country below, and entirely separated from the Tivoli hills, offer another magnificent proof of the grandeur of the phænomenon which produced the old or ante-historic travertine.

These quarries have been made in one of the faces of a vast flattened dome occupying many square miles, the highest points

of which are at some altitude above the river Anio. Charged as it is with fossilized seeds and marsh plants, this travertine was doubtless formed at a period when the waters covered all the lower region of the Campagna, or when very copious mineral springs were in action. It was therefore accumulated when igneous and elevatory action was still acting rifely along all the Italian coast,—that action which had given rise to the earliest volcanic rocks already described, and which, when it had ceased to exhibit its most violent phase, seems to have been followed by a copious evolution of gases and acids, which acting on the limestones of the adjacent Sabine Hills and their outliers that surround this tract, derived therefrom the continuous and rapid additions of old travertine, and saturated therewith very extensive tracts. The small lakes of the Solfatara and Tartaro are now the only remaining vestiges of the former intense energy which produced the wide-spread masses of old travertine. Explained by Davy and chronicled by Lyell, they only acquaint us with the mode of formation on the present minute scale. As no streams or lakes have existed during the historic æra in any portion of the great adjacent low plateau of travertine, with the exception of the pools above mentioned, any more than on the western slopes of the Tivoli Hills, the formation of the enormous breadths of travertine exposed in these localities must be referred to the close of the great subaqueous volcanic epoch which was terminated by the elevation of the Campagna. He who examines the flanks of the Apennines and their recesses, will find, I doubt not, many other masses of travertine equal in extent to those of Tivoli. Such, for example, fell unexpectedly under my own notice as I was returning from Naples by the middle road, where to the north of Ferentino I saw the apennine limestone and superposed macigno covered on their edges by a great breadth of honeycombed, hard, dry travertine, which extended over the broad valley in rough and undulating hillocks occupying many square miles, and surrounded, as near Tivoli, by the volcanic tuff which near Val Montone fills up all the rest of the trough between the Sabine and Latian Hills, and rises to a considerable height on the flanks of the latter.

When we contrast these grand operations of ancient nature with the deposits of existing lakes and rivers, we at once see, that there is the clearest line of separation between them, dependent in fact on great changes in physical geography. Thus, the above-mentioned tract of hilly travertine between the Volscian and Sabine ridges of apennine limestone is separated from all the drainage of the Anio and the Tibur and the Campagna di Roma, by a "divortia aquarum" composed of volcanic tuff. Again, whilst the ancient deposits of Tivoli have taken place where the course of a river, still charged to some extent with lime, may under very different outlines serve to explain the *modus operandi*, here, on the contrary, there is no stream, solfatara, nor lake; a few pebble rivulets, the feeders of the Garigliano, being alone visible at the base of the hills. This travertine tract, then, has also been accumulated towards the close of the earlier volcanic period, and after the tuff of the Campagna had to a

great extent assumed its present outline and constituted terra firma and natural barriers.

But to return to Tivoli and there compare the present operations, in the formation of travertine, with those of former days.

We there see, that all the calcareous matter which the river or its Cascatelle have added to these ancient deposits, since the Temple of Vesta and the Villa of Mæcenas were built upon them, is so mere an incrustation, that if it were necessary to estimate the age of the ante-historical or earlier travertine by such a scale, we should have to recede millions of years to account for its dimensions. When we reflect, however, upon what must have been the condition of things when the whole of this coast region was the scene of powerful volcanic activity, there can be no difficulty in imagining how vast quantities of travertine may then have been spread out in a comparatively short time; whilst the limited and slow supply of the modern travertine is perfectly intelligible, now that volcanic action is either entirely dormant, or only exhibits here and there feeble signs of its subterranean existence.

In reference to the enormous dimensions of the old travertines of Tivoli, Sir Charles Lyell has expressed his belief, that they may have been formed in a deep lake, or in lakes similar perchance to one of those which have been let off in the historic period along the upper course of the Anio. But I cannot believe that the lake in which the old travertine of Tibur was formed, could have been in existence during the occupation of Italy by the human race, as my friend leads us to infer by his mention of the discovery of the impression of a cart-wheel in an upper portion of this rock. This circumstance can, it appears to me, be much better accounted for by what has recently occurred at Tivoli, and without connecting the ancient travertine with the works of man.

The river Anio has, as is well known, escaped from the flank of the Apennines for ages, both by a principal channel between the great plateau of travertine on which Tibur or Tivoli has been built, and the adjacent ridge of secondary (cretaceous) limestone, and also by numerous underground currents which find their way through the cavities and recesses of the travertine to issue in the Cascatelle. In fact, the hard impervious cretaceous limestone on the right bank of the stream has been for ever throwing off the waters, and forcing them to undermine the softer old travertine on the left bank, and as the necessary result, a city built on a porous substratum so assailed at high floods, has been subjected to great periodic calamities.

It was to obviate the recurrence of these misfortunes, that the Cavalier Bernini, in the 17th century, opened out a new and straight channel through the eastern portion of the travertine, which carried the chief body of water into the chasms so much admired under the Temple of Vesta, whence it cascaded through the grottoes of Neptune and the Syren down to the lower falls. At length even this remedy proved inefficacious, probably owing to the channels of escape getting choked up by increasing layers of calcareous matter, and

during a high flood in 1826 a great calamity occurred. Having risen suddenly to some height above its maximum level, the water, unable to escape, was thrown back so violently against the south-eastern corner of the town above the bridge, that it broke away the travertine cliffs, and with their fall demolished the church of S^ta^ Lucia and thirty-six houses, nearly all the transportable materials of which were hurled down torrentially through the cataracts and falls. In this transport it happened, that some of the largest beams of the church stuck fast in the grotto of the Syren, and one of them in particular still remains like a bone in the gullet of an animal, and will doubtless in due time get buried in travertine, which though formed only a few years ago, is *apparently* subjacent to a great mass of rock, accumulated, I have no doubt, before the Roman æra. As in future ages this beam of a church (and many other materials) may be found lodged or deposited apparently in the body of the travertine, it might be inferred (particularly as the course of the Anio has now been greatly changed) that the church rafters were contemporaneous with the formation of the ancient travertine. In like manner I believe that the cart-wheel alluded to by Sir C. Lyell may have been transported at a comparatively recent date, and was by some such operation wedged into a recess of the older rock.

In truth, the travertine formed only a few years ago cannot easily be distinguished, if at all, from that of the post-pliocene period. Agreeing therefore with Sir C. Lyell, that the greater portion of this calcareous formation was accumulated in lakes, which he admits may have been for the most part anterior to the æra of history, I differ from his inference, that any portion of the lake, in which the old travertine on which Tivoli stands was accumulated, could have been undrained when the cart-wheel in question was deposited. The natural sections which expose the edges of the strata of volcanic tuff, covered by great bands of travertine, in the cliffs far above the Campagna di Roma (see fig. 2, p. 290), must convince us that the physical outline of the region was very different from that which now prevails, when such travertine could have been accumulated in a lake of which we nowhere see the western barriers*.

There can then be little doubt, that all the earlier volcanic rocks of the Campagna di Roma, and the great travertines which accompanied or followed their evolution, were formed under subaqueous conditions. The marine animals of the former sea were associated with and succeeded by spoils of terrestrial life washed

* The noble and spirited work executed in the Pontificate of Gregory XVI., to prevent all such catastrophes as that of 1826, gives a straight and direct issue to the great body of the Anio, by a magnificent tunnel cut right through the promontory of apennine limestone, called Monte Catillo, which has for so many ages thrown off the waters upon the travertine plateau of Tivoli. Though a capital piece of engineering and highly useful, this work will however assuredly fall under the anathema of all lovers of the picturesque, who never can endure the comparison of the present straight and smooth fall of the chief mass of water with the old upper falls, the beauty of which is now to a great extent destroyed by the loss of two-thirds of the water which formerly rushed down them. Still the grottoes are well-worthy of being visited.

down from the adjacent Apennines, which then alone constituted the "terra firma" of Italy, and from the character of some of the youngest of these remains (of which I spoke in my last communication) as well as from the nature of the travertine, we infer that the waters passed from a saline to a freshwater condition. This latter period was, I believe, coæval with part of the younger pliocene deposits of the sea, and the enormous changes in physical outline which have occurred since that time in the south of Italy and Sicily are well known to all, and particularly through the labours of Sir Charles Lyell.

Volcanic Rocks of Latium.—The only apparently valid evidences in favour of the former existence of true subaërial volcanos in the Papal States, are those which occur in the Latian Hills to the south of Rome, where Medici Spada and Ponzi have convinced themselves that such phænomena have prevailed. On examining these hills, I could not, however, embrace the entire view of those authors; for although, from what I shall presently state, there is ground for supposing that a central portion of this tract was a true volcano, it appeared to me that the depressions occupied by the lakes of Albano and Nemi came under the same general category as some of the lakes north of Rome (Bolsena, Baccano, &c.), and were therefore excluded from terrestrial conditions*. Independently of their peculiarity of mineral structure, it is stated by Spada and Ponzi, that all the dejections which slope down from the Alban Hills overlap the tufas of the Campagna. One of the most striking of these is said to terminate in the well-known basaltiform mass at Capo di Bove, or the tower of Cecilia Metella near Rome; but I confess I was unable to observe anything like the continuance of what might be called a *coulée* from the Alban Hills to that classic spot. The rock, it is true, contains melilite and pyroxene, minerals of the Alban or Latian system, together with Wollastonite and pseudo-nepheline. Difficult as it is to trace the continuance of such so-called lava-currents, owing, as I think, to great denudation, erosion, and change of outline subsequent to their emission, the traveller perceives that in proceeding southwards from Rome, he leaves behind him, as Ponzi pointed out to me, those broad sweeps and wide undulations which principally characterize the Campagna, and when about nine miles from the city he mounts on the rapid slopes of the Alban or Latian Hills. In comparing the ground and subsoil on which he then stands with that to which he looks back, he already sees that masses of inclined dejections having a certain community of character radiate from a common

* In their theoretical profile showing the arrangement of the rock masses in the Campagna of Rome, Spada and Ponzi attempt many subdivisions of the deposits above the subapennine strata. Thus, their lowest lavas are trachyte and tephrine basalt overlaid by the tuffs, scoriæ, lapilli, and puzzuolane of the Campagna. These are all considered submarine; but then they are overlaid by the tufaceous marine limestones and travertines of quaternary age, and are followed by tephrine basalt, sperone, and peperino, all of which are considered terrestrial, as well as the younger group of tuffs, scoriæ, and lapilli of the Latian volcanos. These last have been alone succeeded by the relics of the Mediterranean sea and modern fluviatile and lacustrine deposits.

centre in the form of great bands. Long, however, before I reached the ascent to Albano or Frascati, occasional and isolated blocks of a very different sort of lava were pointed out to me by Ponzi. These contain crystals of pyroxene, and he supposes that they have been hurled from a quondam volcanic orifice in the Latian Hills (such as the Camp of Hannibal, to which I shall hereafter specially advert), and projected to their present habitats in the Campagna distant ten miles from the supposed source of their origin. I shall, however, endeavour to account for the dispersion of these materials in another manner, before I close my description of these Latian volcanos.

In ascending from the Campagna to Castel Gandolfo and the Lake of Albano, immense sloping mounds of grey peperino, fig. 3, 3, & fig. 4, 3, 3, are exhibited, in which, in addition to numerous crystals of leucite and occasionally other simple minerals, there are large angular fragments of Apennine limestone, some of which are in a highly altered state, and also portions of pre-existing crystalline rocks, containing mica, pyroxene, garnets, and Hauyne. I confess that I could not see any great geological distinction between the compact leucitic peperino, which occupies the high point on which the convent of the Cappuccini stands, as well as the cliffs around the beautiful, deep, oval-shaped Lake of Albano, and the leucitic rocks of Bolsena and Acquapendente before described; nor can I believe that there was any great difference in their age or in their method of emission. For here, as in the so-called parasitic crater-lakes north of Rome, the high walls or banks of the Lake of Albano are completely unbroken, without the semblance of any gap or opening by which a *coulée* of lava could have flowed. It is true, that about a mile to the south of Albano, and nearly on the same level as that town, a new cut in the road, made in establishing a bridge, has exposed grey leucite lava, overlying unconformably the ordinary reddish tuff of the Campagna; but half a mile further on, at Lariccia, these two rocks are conformably arranged, and the same system and relations continue to Velletri and Cisterna. Now if the red tuff, which is admitted to have been a subaqueous deposit, had been elevated into land before the peperino and grey lava flowed upon it, surely we might expect to see some trace of a terrestrial surface, some dirt-bed with remains of vegetable substances between the two rocks; but such is not the case, and the one is at once incumbent on the other.

In mounting from the outer portion of the circle, or from the level of the rocks which encompass the Lake of Albano to Rocca Papa and Monte Cavi (the culminating point of this cluster of hills, on which the Temple of Jupiter Latialis stood), it seemed to me, that near a little chapel the upper courses of the peperino, or outward fringe of rocks, alternate with, and are finally overlapped by, layers of scoriæ and lapilli of a brownish red colour*. Still higher

* Though I came to the conclusion that the scoriaceous lava overlaid the peperino, I beg that my cursory researches may be well tested before they are allowed to prevail against the inferences drawn by local observers. I gather, indeed, that Hoffmann viewed the succession in somewhat the same light as myself; for, although he enters into no details, he explicitly states, that the isolated

up, and reaching Rocca Papa, all traces of the peperino vanish, and from thence to the summit of Monte Cavi, about 3100 feet above the sea, the whole mass consists of a portion of that grand scoriaceous and cindery accumulation which forms the circumference of the depression called Hannibal's Camp, fig. 3, 4, and 4, 4, 4. Very different, indeed, from that peperino, which I consider to be subjacent (or formed under different conditions), are those scoriaceous dejections which have, to a great extent, a terrestrial or atmospheric aspect. Here also, in physical outlines, we reach something like an analogy to the phænomena of Auvergne; for we see that one of the faces of the brim which encircles the depression in which Hannibal encamped (*i. e.* to the north-west) is broken down, as expressed in a map of the tract prepared for my use by Professor Ponzi (fig. 3, p. 284). Again, all the rocks surrounding this semicircular cavity bear signs of subaërial volcanicity. Scoriaceous fragments and loose lapilli are arranged in fine laminæ, unlike the great amorphous masses of the Alban peperino, and they are associated with what much resembles portions of *coulées* of lava. I further observed tortuous, rope-shaped coils of scoriæ, like those which so abound at Vesuvius, and spherical and flattened geodes of the same substances. Again, these volcanic dejections are traversed by dikes like those of Somma, the modern analogues to which are even seen in Vesuvius. When, however, we come to judge from the mineral characters of all the associated rocks, there are difficulties in identifying some of them with known subaërial productions. Thus, there are apparently issues of matter which the Italian geologists call tephrine lava, containing calc spar, Gismondine, and pyroxene, and which, but for the difference of the imbedded simple minerals, pointed out to me by Spada, I could not distinguish from those basalts of Radicofani and Acquapendente which were unquestionably formed under the waters. There is also a greenish leucitic rock with crystals of dark pyroxene, together with some olivine. Again, there is a very peculiar lava in these dikes and *coulées* in the form of a roughish, light, and somewhat porous trachytic rock, called 'Asprone' by the country people ('Sperone' of authors), which near Rocca Papa is copiously charged with small garnets. It is this 'Asprone' which is largely quarried as a building-stone in the adjacent hills of Tusculum.

In respect to the general relations of Hannibal's Camp, it must be admitted, that as all the scoriaceous accumulations occupy hills from 500 to 700 feet higher than the valley they encircle, and as their strata dip away from it, and also have a broken-down orifice on the north-west, the whole scene, as well as the lithological aspect of the rocks, leads to the belief that this may have been a subaërial volcano. At the same time, if such it has been, the volcanic action must have been of very remote antiquity. In proof of this, the sandy and

mountain, of which Monte Cavi is the highest point, is "probably the only crater in the Papal States from which a perfect volcano or volcanic cone, like that of Vesuvius, still rises up, which has been active *since its emergence from the sea.*" (See Geognostische Beobachtungen durch Italien und Sicilien, von F. Hoffmann. Berlin, 1839, pp. 47, 48.)

marly subsoil of the central depression is seen to be a lacustrine deposit, fig. 3, 5, & fig. 4, 5, which is charged with *Lymneæ* and *Planorbes*, whether of extinct or living species I could not ascertain. It is, therefore, clear, that if ever Hannibal's Camp were the crater of a true terrestrial volcano, as I believe it may have been, its activity ceased at a very early period, and the depression became in subsequent ages the station of a lake which in its turn was let off, and the ground desiccated, probably ages before the Carthaginian invasion! A remarkable feature in this depression is, that precisely in its centre is a conical hill called 'Monte di Vescovo,' formed of the same volcanic materials as the surrounding margin, the escarpment of which is nearly equidistant from the central mount at all points (see Map, fig. 3, page 284, and section, fig. 4).

Besides the chief central crater or Camp of Hannibal, there are two other parasitic and smaller adjacent craters, one of which is called La Tartaruga, which lie immediately to the south of it, in the valley of La Molara, which separates the group of Hannibal's Camp from the sloping ridges of Tusculum on the north. Whether viewed in nature or on the Map (fig. 3), these smaller craters certainly much resemble some of those in Auvergne, and, like their larger neighbour, they have each broken-down rims on their north-western faces. It is also probable from the nature of the rocks, that the same volcanic matter, which issued in Hannibal's Camp and its parasites, also forced a vent in the Lake of Regillus, and at Colonna on the north, and at Civita Lavinia on the south of this system.

Having already expressed my opinion that the flanking masses of Alban peperino are of higher antiquity than the scoriaceous rocks of Hannibal's Camp and Monte Cavi, I may say another word or two, better to explain why I thus differ in opinion from my friends Spada and Ponzi. These authors suppose, that the peperino was formed upon land by a sort of lateral mud eruption which issued from the side of the great subaërial volcanic vent. They base their inference chiefly on the fact, that some grass-like vegetables have been found within the peperino which have their stalks pressed down conformably with the slope of what they consider to be the former *coulée* of mud in which these vegetables descended; and hence they suppose that the peperino flowed upon *land*. Seeing that these vegetables have not been torrified or carbonized, these authors explain this circumstance, by saying that the mud issuing from the volcano, though hot, was not in a state of fusion. Again, they spoke to me of bones of deer having been found under the ruins of a house at L'Arricia as a proof of terrestrial conditions. But the latter observation had not been verified by their personal inspection when I left Rome, and even if it be in all respects correctly stated, it does not, as it seems to me, establish their case. Masses of matted sedge-like vegetables which grew upon the adjacent Apennines only three or four miles distant, and the bones of deer which fed upon these grasses, may both have been very naturally washed into the waters bathing this coast, at the period when those igneous operations were in activity which I presume gave rise to the solid and massive peperino

in the form of subaqueous detritus. This supposition is, indeed, fully confirmed by all the accompanying phænomena in the Campagna around Rome, where skeletons of elephants, rhinoceros, deer, and other quadrupeds are not only found in the subapennine marine strata, but also in the subsequently formed igneous rocks and travertines; and to none of these deposits has any other origin been assigned, than that of accumulation *under water*, whether salt, brackish, or fresh. When I examined the grand and deep quarries of peperino near Marino, and between that place and Albano, and saw their amorphous and solid character, I had no doubt that they were of anterior date to the higher and central scoriaceous eruptions of Monte Cavi, which, as I have stated, alternate with and overlie peperino. If this peperino had been emitted as a lateral outburst of hot mud whilst the central volcano of Hannibal's Camp was active, and had flowed upon ground which had then assumed its present form and terrestrial conditions, surely we should see in it something like a lava formed under the atmosphere, and its surface, if not rugged, would, at all events, be more or less porous and scoriaceous, and not the hard, compact building-stone which it is. I could see no sort of evidence to prove that the peperino of Marino was of a different age from that of Albano; on the contrary, I believe that they are integral parts of one and the same subaqueous matter, ejected under pressure around the roots of a group, whose central cone and crater were rising into the atmosphere.

If then we are to admit, that there is any true analogy between Hannibal's Camp and authenticated subaërial volcanos, we must allow, that the most modern dejections are those which proceeded from the higher crater, whilst most of the great amorphous lateral masses may very well be referred to an anterior period, and to formations accumulated under other conditions.

In viewing the Latian Hills as a whole, I should therefore say, that their flanking cavities, still filled with water, whether cup-shaped like Nemi, or elliptical like Albano, are to a great extent analogous to those of Baccano and Bolsena, north of Rome. I believe that, together with the igneous rocks which form their banks, they were accumulated under more or less aqueous pressure, and never were true subaërial volcanic vents; though they probably were apertures produced by the explosion of heat and gases when all the volcanic materials were under water. On the other hand, the true crateriform depressions of Hannibal's Camp and its parasites were, as I think, the lofty spiracles by which the volcanicity was let off,—viz. when the grounds were emerging, or had partially emerged from the sea, and were attaining their present outlines. The probable result of this last operation in the series of elevations and eruptions might be, that by the rising up of the central volcano the surrounding and pre-existing masses would radiate from it and slope down into what is now the adjacent low country, as they now do, and thus be in this sense a crater of elevation. I may further observe, that on inspecting this system of hills I was impressed with the idea, that, whilst its uppermost dejections bore some resemblance to the extinct volca-

nos of Auvergne, still I could nowhere see any such decisive proofs of terrestrial volcanicity as the French tract affords in its most recent *cheires* or *coulées*, and their direct issue from the broken-down lips of craters. I came away, indeed, under the belief, that the youngest volcanic rocks of Latium were probably formed anterior to the last active volcanos of Auvergne; such, for example, as the Puy de Tartaret, which I formerly examined in company with Sir C. Lyell, and which has subsequently had such decisive proofs of its modernity adduced by my associate *. In other words, I apprehend, that in Latium they formed the last part of a continuous series of active igneous operations, which being submarine and to a great extent subpaludine in its origin, assumed gradually (whilst the land was emerging, or very shortly after its emergence) those intermediary and peculiar features which characterize the upper dejections of the Latian Hills. I would further suggest as highly probable, that whilst the old travertines near Tivoli were accumulating, the Latian eruptive forces spent their last energies as active volcanos. This view is also borne out by the striking mineral distinction between these Latian rocks and those of the Campagna di Roma and the Colles Ciminii north of Rome. The Latian rocks not only contain several simple minerals, above enumerated, but are exempt from the felspar so common in the northern tract. In admitting the value of this distinction (indicated by Monsignore Spada), as respects the younger or true volcanic rocks of Hannibal's Camp, La Tartaruga, and Tusculum, I cannot consent to group in the same category the peperinos and leucitic rocks of Albano and Marino. The mere absence or presence of one or more simple minerals cannot stand in the way of geological phænomena and general physical conditions which indicate that this region was manifestly to a great extent subaqueous all around the Latian volcano when the latter was in activity. If, indeed, we are to appeal to mineral characters, even then I contend, that it is quite impossible to separate the peperino of Marino from that of Albano, or the latter, when coarse-grained, from the leucitic peperino forming the outward dejections of Rocca Monfina, which, as I shall hereafter show, were unquestionably formed under water. Again, though Spada furnished me with specimens of what he called stratified cinder-beds between the banks of the Alban peperino, I ask any unprejudiced person to compare these with other rocks ticketed by the same good mineralogist as tertiary tuffs from the Tre Fontane, and with the feathery light scoria, with crystals of vitreous felspar, and the pumice from near Veii and other places north of Rome, where subaqueous conditions are admitted by him to have prevailed, and then say whether the peperinos from the Ciminian or those from the Latian tract have the most subaërial aspect.

That all these eruptive operations, even the last in Latium, were anterior to the desiccation and elevation of the "quaternary" accumulations of Italian geologists, which fringe the shores of the Papal States in the form of raised beaches, is indeed distinctly proved by the discovery, that the bibulous travertine of that age called "Macco,"

* See Quart. Journ. Geol. Soc. Lond. vol. ii. p. 75.

which occurs at Porto d'Anzo*, imbodies fragments of rocks derived from what I have shown to be the newest portion of the Latian volcanos, and in addition to leucite contains crystals of pyroxene and peridote; minerals which first made their appearance in the volcanic products of that time, and have not been detected in the more ancient tufaceous and igneous rocks of the Campagna. Now, Porto d'Anzo or Antium is about twenty-five miles distant from Hannibal's Camp, and as a volcano of its small size could not be expected to eject solid contents to a distance far beyond that to which Vesuvius now occasionally projects fragments in showers, so we have a right to infer, that when the Latian volcano was in activity, the sea approached very near to its periphery or roots. In this case we should have no difficulty in accounting for the washing away of its materials to the spot where Porto d'Anzo now stands, there to form part of the Mediterranean deposits which were afterwards to be elevated, constituting the raised beaches of "Macco." In like manner I would explain the transport of the huge blocks of the Latian volcanic rocks to the neighbourhood of Rome before adverted to. At all events the facts at Porto d'Anzo are sufficient to prove that the relations of land and water have undergone very great change since the activity of the youngest of the Latian volcanos; and it appears to prevent our extending true terrestrial volcanicity beyond the limited area in this region to which I have attempted to restrict it†.

Rocca Monfina.—I now beg to say a few words upon that remarkable volcanic tract, called Rocca Monfina, in the kingdom of Naples, which has been described by several foreign authors‡, to which Dr.

* On the authority of Professor Ponzi. The quaternary of some Italian geologists is supposed to have been formed since the habitation of the peninsula by man, but this point is not well established.

† After these pages were written, I learnt that Professor James Forbes had read a memoir on the Latian volcanos before the Royal Society of Edinburgh, on the 29th January 1850. On communicating with him, I find that he differs from me as to the origin of the Lake of Albano and its peperino, and agrees, as far as I understand, in the main with the views of Spada and Ponzi. As Prof. Forbes has paid more attention than myself to the mineral structure of the Alban rocks, my readers must necessarily consult his forthcoming memoir, of which I have only seen the abstract. He thinks that the land was already covered with vegetation when tremendous outbursts forced open the cup-shaped cavities of Albano and Nemi, and that mud eruptions from lateral orifices were poured forth since the ground assumed its present relations and outline (as at Marino). He seems to believe in three periods of peperino and lava dejections, all subaërial. To these views I cannot subscribe, for the reasons adduced in the text. I cannot imagine that the deep lake depressions of Albano and Nemi, with their solid lofty cliffs and unbroken sides, were ever subaërial volcanos. Nothing like these, I would suggest, has ever been formed by volcanos in modern ages: nor do I comprehend how the enormous thick masses of peperino which are opened out in the quarries of Marino, should have issued from the extreme, external, and lower flank of a volcanic group, which, according to the admission of Spada, Ponzi, and Forbes, must have had (and probably, as they say, at the very same time) an unchecked orifice in the great central crater of Hannibal's Camp. I repeat, that it is with diffidence that I oppose this portion of the view of these my friends and contemporaries, but, with my present knowledge, I adhere to the line I have adopted. In considering the chief Latian volcano subaërial we are all agreed.

‡ See *Breislak*, Voy. Phys. et Lithol. dans la Campanie, 1801; *Abich*, Ueber

Daubeny* called the special attention of British geologists, and whose relations were critically discussed by Mr. Horner in his discourse as President of the Geological Society in 1847.

This lofty tract, the interior of which was, as Daubeny has shown, the stronghold of the warlike Aurunci long before Rome had acquired its great power, lies between Sessa on the west and Teano on the east, and derives its present name from a high rock of solid trachyte (Monte della Croce) which rises in the centre of a grand upland crateriform depression, and is about 3300 feet above the sea. This high tract is shut out from the circumjacent low countries or bays in the apennine limestone by a more or less circular ring of eminences of different altitudes, the highest of which, called Monte Cortinella, is nearly as lofty as the central mountain; whilst the others are of much less altitude, being on an average not more than 300 or 400 feet above the upland depression. They constitute, on the whole, a brim or margin surrounding the circular depression, from the centre of which rises the above-mentioned trachytic mountain. These eminences of the margin differ, however, essentially in their composition from that of the central mountain. They consist of tuff, scoriaceous rocks, and peperino with pumiceous or trass-like dejections, whose outward slopes extend on all sides into the surrounding low country, as if radiating from a common centre. In circular arrangement, and even in having a central boss, Rocca Monfina is analogous to Hannibal's Camp in the Latian Hills; but when we compare the two tracts, essential distinctions arise. Thus, the central boss at Hannibal's Camp is of the same composition as the immediately surrounding dejections of Monte Cavi, &c.; whilst at Rocca Monfina the centre and flanks are of such very different structure, that the one must have been formed separately from the other.

Pilla had remarked that the culminating-point of the central mass of trachyte, or the Rocca, is precisely equidistant from all parts of the escarpment of the surrounding dejections†; but he omits to state, and I do not find it noticed in other authors, that portions of the same trachyte protrude in lower bosses between the main mass and the environing brim. This feature, however, I particularly observed to the south of the hamlet of Casa Fredda, where a mount of trachyte occurs upwards of half a mile distant from the slopes of the chief mass of that rock, and consequently near to the surrounding belt of volcanic hills.

The diameter of the crateriform cavity is about two and a half miles,

die Natur und den Zusammenhang der Vulcanischen Bildungen, 1841; and *Pilla*, Annales des Mines, 1841, and Saggio Comparativo, 1845.

* See Dr. Daubeny's Memoir, Transact. of the Ashmolean Soc. Oxford, 1846; and also printed in the New Edin. Phil. Journal, vol. xli. p. 213. I visited Rocca Monfina from St. Agata and Sessa at the end of February 1848, and passed along its eastern flanks in the following month on my return from Naples to Rome.

† I presume that Pilla could only mean, that the escarpment of the limited portion of the brim called the Cortinella described an arc exactly equidistant in its parts from the summit of the Monte della Croce; but this is very different from the interpretation usually accepted.

and the section, fig. 5, p. 284, gives some idea of the relations of its brim to the central trachyte.

By reference to the section (fig. 5) it will be seen, that however the *summit* of the Monte della Croce be nearly equidistant from any portion of that part of the adjacent brim properly called the "Cortinella" (as insisted on by M. Pilla), the centre of the trachyte is nearly double the distance from the less elevated segments of the brim south and east of the village of Rocca Monfina; and therefore it is, that the occurrence of some trachyte *in situ* which I observed in the intervening valley is of importance in leading us to any sound theoretical inference. At the same time, no clearer geographical proof can be given that the chief mass of the trachytic mountain is not in the centre of the crater, than that in proceeding from Sessa to the town of Rocca Monfina, the traveller having ascended by the chief watercourse on the west by which mills are turned, and having passed through a gorge in the volcanic brim, thence traverses the crater directly from S.S.W. to N.N.E., without touching upon the steep southern face of the Monte della Croce, which he leaves about half a mile on the left hand.

Nothing can be more in contrast than the central trachyte of the Monte della Croce and the dejections which surround the crater and dip away into the surrounding low countries. To a person unaccustomed to trace the transitions between submarine volcanic rocks and those formed in the atmosphere, it would necessarily appear difficult to distinguish some of those dejections which slope down to Toro di Sessa and Sessa (such as the scoriaceous masses with some lapilli) from what are now forming in Vesuvius; but on the other hand, he will, on careful scrutiny, observe that these graduate into, and *alternate with*, hard leucitic rocks and peperino (quarried as millstones) and amygdaloids, both of which are unlike modern productions, and have a porphyritic cast*. The distinctions between these external productions of Rocca Monfina and the modern ejections of Vesuvius are indeed strikingly exhibited in the crystals of leucite, which in the former or more ancient rock range from half an inch to 2½ and 3 inches in diameter, whilst in the showers of Vesuvius they do not exceed the size of peas†. Again, instead of true pumice, he meets with vast mounds of white felspathic aqueously-formed trass, from which the Fiume Bianca and adjacent rivulets have derived so milky a colour and so unwholesome a character, that to improve the health of the population, it was deemed necessary to construct an aqueduct, which conveys the purest water to Sessa from the central dome of hard subcrystalline trachyte in which the springs issue. Independently then of the manifest distinction be-

* In respect to the arrangement of the external volcanic dejections, I cannot admit as a general rule that the leucitic lava caps the trass and tuff, as cited by Dr. Daubeny; for in the ravines above Toro di Sessa, I met with numerous alternations of these rocks, including those passages from the one to the other to which I here advert.

† A copious shower of these small crystals of leucite issued from Vesuvius in 1847, and is described by Professor Scacchi.

tween the central and external rocks, this fact alone at once indicates their marked difference.

In advocating the application of the elevation-crater theory to Rocca Monfina (in common with Abich and Pilla), and in separating the central trachyte from the external accumulations, Dr. Daubeny thus speaks of it:—"A conical mass of rock so considerable, and yet so completely circumscribed within the area of the crater, could only, as it would seem, have been brought into the position which it is seen to occupy, by being heaved up all at once from the interior of the globe whilst in a semi-fluid or pasty state, but not in a condition of actual liquidity." In theorizing upon the effects of such elevation of the trachyte, he says:—"We have before us an agent which would be not only competent to uplift the surrounding strata of tuff, but which must necessarily have done so, if the latter had been at the time of its eruption in a horizontal position; and to suppose these gradually formed by successive showers of loose incoherent materials before the trachytic rock in its centre was produced, seems to imply a forgetfulness of the height which the tuff has attained, and the high angle at which its beds are inclined." Now, in my opinion, every circumstance, lithological and geological, is in favour of the inference, that the central trachyte is of higher antiquity, and was originally formed under different conditions than the surrounding dejections. Abich describes the rock as "trachytic dolerite," or an intermede between trachyte and greenstone, which contains much green augite and brown mica; and when on the spot I could not hesitate for a moment, even judging from mineral characters only, in believing the central trachyte to be the oldest rock of the tract. In parts it has almost the aspect of an old porphyry. Nay, Dr. Daubeny's own description of its external aspect would have led me to this conclusion. "Its surface," says he, "so far from presenting the rugged aspect which *volcanic* rocks usually assume, is so uniformly clothed with vegetation, and in such a state of complete culture, that but for the amphitheatre of hills which encloses the table-land on its summit, the circular form of which betrays the origin of the mountain of which it forms the outer margin, no one could dream from its physiognomy that the whole was of igneous formation."

In drawing his conclusions as to the relative age of this trachyte of Rocca Monfina, the geologist ought necessarily to be guided by the analogy of the succession established in the Papal States, Tuscany, and the adjacent Ponza Isles; and enough has already been cited in respect to the hills around Viterbo, to testify that the trachytic rocks were there either the first- or the deepest-born of all the earlier volcanic products. Their order is shown by positive sections and superposition.

The inference of my friend Dr. Daubeny, that the trachyte is the last formed of the rocks of Rocca Monfina, has the more surprised me when I look to the good explanation he has given of the close relations of trachytes to granites, and consequently their greater distinction, as I should say, from modern subaërial volcanic rocks. He traces that beautiful series of transitions, by which primordial granite

has first been converted into trachyte, and *afterwards* into the various kinds of lava which characterize modern volcanos. Putting aside then all analogy, even in Italy, this admission alone seems hostile to the hypothesis, that the trachytic dome of Rocca Monfina should have been heaved up all at once to its present altitude *after* the accumulation of the scoriæ and lava on its flanks.

In recognizing the distinctions between trachytic and basaltic rocks, their isolation and yet connection, Von Buch and Humboldt show that occasionally in Europe, and often in South America, basalt is superposed to trachyte. "Tantôt," says Humboldt, "ce sont de larges coulées de basaltes souvent interrompues et formant des gradins et des plateaux qui sillonnent et recouvrent ce terrain*." According to Brongniart, trachyte is the granite of plutonic rocks, and is almost as much extended over the surface†.

In placing the trachytes immediately after the serpentines, and before all subaërial volcanic rocks, Pilla is in accordance with all the Italian geologists‡. The same author, in his 'Richezza Minerale delle Toscana,' p. 151, includes the trachyte of Monte Amiata and the grey basalt of Radicofani under the term "piroidi," and completely separates them from volcanic rocks. I have no doubt that trachyte has been raised to the surface at different periods; for General La Marmora has shown that the Sardinian trachyte was erupted anterior to the deposition of the subapennine strata. Other trachytes, as in the Euganean Tuscany, the Papal States, and Ponza Isles, are of posterior date, and probably contemporary with the younger granitic rocks of Elba; whilst the trachyte of Ischia alternates with existing marine shells. In regard to Rocca Monfina, Pilla is of opinion that its volcanic dejections were emitted during what he calls the old alluvial (drift or diluvial) period, and were re-aggregated and transported to distant parts by aqueous action§.

Whether we regard the structure of its rocks or their close analogy to similar masses in other parts of the world and in Italy, my conviction is, I repeat, that the trachyte of Rocca Monfina is the oldest rock of the district, and was formed under different conditions from the surrounding dejections, and under much more pressure. But how and when was this mass of trachyte placed in its actual position? For even if the analogy of the Papal States were wanting, I should have the greatest objection to admit that this rock could have been formed under the same conditions as the surrounding loose dejections, much less that it could have been so raised up into the atmosphere.

From my own observation, indeed, I never could see any good grounds for believing with Mr. Poulett Scrope‖ (much as I admire and subscribe to his views concerning the true volcanos of Auvergne),

* Humboldt, Gisement des Roches, p. 335.

† Al. Brongniart, Classification des Roches, p. 116.

‡ See Trattato di Geologià, p. 13.

§ See Saggio Comparativo, p. 10, Pisa, 1845; and "Osservazioni geognostiche sulla parte settentrionale ed orientale della Campania," Annali Civili delle due Sicilie, fasc. vi.

‖ See Volcanos of Central France, p. 58 *et passim*.

that the trachytic rocks of the Mont Dore could have been formed under the atmosphere, or under the same conditions as the surrounding and lower craters. The trachytes and even the domites of that region were, I believe, the earliest-formed rocks along that band of eruptive agency, and were in existence before the outburst of true terrestrial volcanicity. These trachytes may have been formed before the region was entirely drained of the great lakes, which we know prevailed in it. The trachytes of the Rhine, the Siebengebirge, of Hungary, of the Ponza Isles, so well described by Mr. Scrope, as well as those of the Papal States, and lastly those of Ischia, whether we judge from their mineral character, the part they have played, or their physical outlines, all convey assurance to my mind that they were accumulated under water. I look upon them therefore as rocks intermediate between those termed plutonic and volcanic; which were accumulated under pressure and at greater depths, whether under water or heaps of other volcanic materials, and were sometimes subsequently heaved up to their present positions. In supposing this manner of formation, even the symmetrically central cone of the Puy de Chopine, so well delineated by Mr. Scrope, may be accounted for. There, as in Rocca Monfina, the central cone of trachyte may have been the result of the last grand eruption, and from its structure and dimensions may have plugged up the whole of the original crater. In the Auvergne case we have only to believe, even if the lands were then desiccated, that the liquefaction of the trachyte took place at some depth, and that when it was raised by the last grand effort towards eruption, the overlying dejections, finding a vent in small craters, were thrown off as a mantle around it.

But to return to Italy. In the northern part of the Papal States the order of superposition would indeed lead us fairly to infer with Pareto, that the trachyte was the first-born of these submarine volcanic products, and was succeeded by the scoriaceous dejections which there overlie it; but if at Rocca Monfina this conical mass should extend downwards, as there is every reason to believe it does, from the discovery of another protrusion of the same rock, so as to occupy a wide base, as expressed by the dotted line (fig. 5), it would in such cases occupy all the crateriform depression, and we could not then picture even to our imagination the source of the supposed subsequent scoriaceous dejections, particularly those of the lofty Cortinella. In other words, the vent would have been plugged up by the emission of the trachyte.

Granting, then, that the uprising has been the last operation, and that the trachyte has been so protruded as to have *raised up* still more, and to have increased the inclination of, the surrounding dejections, it must have been at that time in a solid state. I do not doubt that the circumambient loose materials had been ejected from a great crater previously to the uprising of the trachyte from the same cavity. They may in the first instance have sloped away at angles of 8° or 10°, and have been afterwards in certain parts raised to 20° and 30°, as we now see them.

In reference to the absence of transverse fractures so pointedly argued upon by Mr. Horner*, I have not sufficiently examined the tract to decide affirmatively that the surrounding brim has no break in it which might have been increased, if not produced, by the uprising of a central mass of trachyte; particularly if we are to suppose, that that mass, being of a conical shape, widened so much downwards, as I have supposed, as to plug up all the area of a former grand submarine crater. For the most part, certainly, the external furrows on the surface of the dejections which slope down into the surrounding country are only what might be supposed to result from thousands of years of atmospheric agency; but the chief cavity in the south-western side above Sessa, by which the principal water-course escapes, is certainly so deep and precipitous that it might be supposed to be a rent resulting from strain or fracture. In deciding cases of this nature, however, every geologist knows that the clear data which present themselves in limestone, sandstone, and schists are often wanting in volcanic rocks. But however this may be, neither the gorge alluded to, nor any other aperture, affords traces of a subaërial *coulée* of lava. The eastern side is alone marked by a broad general depression of the brim, which so dies away that the crater may be said to open out to that side by a gradual and undulating slope, leading down into the valley of Teano. But here again we in vain look for anything like a lava-stream, or even the remains of one which issued from a true terrestrial volcano; whilst in the erosion of the hillocks, as in the characters of the surrounding tuff, we recognise only subaqueous action and denudation. My impression therefore is, that the external tufaceous dejections of Rocca Monfina were vomited from a great *submarine* crater, and were in the first instance probably arranged with a certain amount of quâ-quâ-versal dip, some of them acquiring an almost subaërial aspect, by having been projected into the atmosphere before they fell back again into the sea, and that afterwards the activity of this great subaqueous vent was completely stopped up before the terrestrial conditions were completed, by the upheaval of a solid mass of trachyte which either had been formed, or was kept in a state of pasty fusion at some depth. I suggest that this trachyte may have proceeded from the same volcanic centre, which had either been previously in activity, or was continued in activity, at a greater depth, and under either the pressure of water or superincumbent dejections. In a word, Rocca Monfina differs only from the crateriform dejections around Viterbo, in having trachyte placed in the centre of a crater, whilst in these Papal examples that rock is usually a great lateral appendage or back-bone, the formation of which was manifestly either of anterior date, or of subsequent protrusion from a deeper-seated centre.

In adopting this view of the *modus operandi* by which such an apparent crater of elevation was formed, we cannot indeed expect to find the chasm so generally present in atmospheric volcanos, with a lava-current issuing from it. We might, however, look out for a

* See Anniversary Discourse, Quart. Journ. Geol. Soc. vol. iii. p. lxxxiv.

worn-down side resulting from aqueous denudation, and also for such sorts of scoriæ, lapilli, ashes, and pumice as were ejected in the formation of Graham's Island. Now this is just the succession of materials, as far as I can judge, that occurs at Rocca Monfina, the very external folds of its volcanic system being the most scoriaceous and volcanic, whilst the central dome of trachyte has almost the solidity and compactness of a plutonic rock formed under considerable pressure*.

In endeavouring to fix the age of these volcanic operations, we have unluckily no certain criteria or tests to appeal to; for the valleys of the Garigliano on the west, and of Teano on the east, which flank Rocca Monfina, contain, as far as I know, no remnants of deposit with marine or ancient lacustrine remains; but judging from analogy, and from that continuous undulation from this tract into the Phlegræan Fields, I have little doubt that the surrounding tufaceous accumulations are nearly of the same age. But whilst we can attach no exact idea of age to the term "felspathic tuff" of the Phlegræan Fields, there is still a point on which we may rest, viz. that in a general sense all the region between the Bay of Naples and Rocca Monfina, a distance of upwards of thirty miles, and occupying the valleys in the Apennine limestone, both to the east and west of our volcano, is filled up with undulations of earlier volcanic rocks or ancient alluvia, which most authors consider to have been as unquestionably accumulated *under water*, as those of the Campagna di Roma. Now some of the portions of these which flank three sides of the excrescence of Rocca Monfina are unquestionably superior, or of younger age†.

In drawing our conclusions, it is well to remark, that we cannot

* In a sketch of the relations of the rocks in the kingdom of Naples, M. Pierre de Tchihatcheff gives the following as the ascending order in time of the volcanic productions of that region:—1. Monte Gargano and the eruptions along the Adriatic line; 2. Monte Vulture; 3. Phlegræan Fields; 4. Rocca Monfina; 5. Vesuvius; 6. Monte Nuovo. (Coup d'œil sur la Constitution géologique des provinces méridionales de Royaume de Naples. Berlin, 1842, p. 171 *et seq.*) I suspect my clever Russian friend would not have thus written if he had more leisurely examined the country. Thus, in approximating the dejections of Rocca Monfina to those of Vesuvius, and in thinking that the one was the immediate precursor of the other, he seems never to have seen (at least he makes no allusion to) the great and remarkable central mass of trachyte at Rocca Monfina, for he admits that trachyte is the *oldest* of all the Neapolitan volcanic products. The credulity of M. Breislak, who believed that remains of Roman buildings were found under some of the tuff of Sessa, and the error of Pilla, in stating that sea-shells had been found adherent to the mountain of Rocca Monfina, are now both admitted.

† A letter just received from that able naturalist Professor Scacchi of Naples, dated the 25th of January, acquaints me that in two memoirs recently published by him in the Transactions of the Academy of Sciences of Naples, he has more fully developed his views as to the origin and formation of the tuffs of the Campania. He assures me, that without any doubt these accumulations are *posterior* to the dejections of Rocca Monfina. Although there are no positive proofs of the *submarine* origin of Rocca Monfina, Scacchi agrées with me as to the ancient and subaqueous character of the trachyte of Monte della Croce (which he considers almost a porphyry), that has closed a great volcanic vent, the materials around which were ejected anterior to the formation of the felspathic tuffs of the Campania. In

pretend to determine the period of the upheaval of certain masses of these Neapolitan tuffs near the sea, by consulting the marine strata which alternate with them, even in those which contain shells perfectly identical with those now living in the adjacent Mediterranean. In my last memoir I have shown that species of sea-shells still in being have existed previously to terrestrial species now entirely extinct (see Quart. Journ. Geol. Soc. vol. v. p. 237). And if we thus fail in measuring the relation of previous epochs to the historical æra, by comparison of things marine with things terrestrial, still less ought we to venture to approximate all the diversified subaqueous volcanic operations of the Phlegræan Fields, or the Campagna di Roma, to our historical atmospheric volcanos, by any reasoning from a few species of marine shells only.

Conclusion.—In my method of accounting for the origin and present form of the volcanic tract of Rocca Monfina, I shall probably neither satisfy those who contend that it is an elevation-crater, nor those who would explain it by reference to any known example of modern subaërial volcanic action. I do not admit that in this case, tufaceous deposits, once horizontal, were raised by the sudden protrusion into the atmosphere of a dome of trachyte into highly-inclined positions; for I cannot suppose that this was ever the site of a true terrestrial volcano. In the Latian or Alban Hills, however (if my view of the succession of their eruptions be correct), the formation of a subaërial cone and crater may, as it was the last volcanic operation of that tract, be very well supposed to have raised and thrown off the surrounding dejections of previous and subaqueous origin, with more or less of an eccentric dip of slight inclination. In those parts of the Colles Ciminii where there are no central trachytes, as at Rocca Monfina, and no true central volcano of subsequent date, as at Hannibal's Camp, I can see no valid objection to the admission, that some of the strata around the lakes of Bolsena, Baccano, &c., which consist exclusively of stratified igneous products, may have been ejected from these orifices, probably under shallow brackish or lacustrine waters. On the other hand, I can see no reason for doubting that subsequent efforts towards eruption, whether accompanied by upheaval of solid rocks or not, may have operated from the same centre to raise up and throw off still more the surrounding stratiform accumulations. If we deny the possibility of all stratiform quâ-quâ-versal arrangements having either resulted from, or been increased by, upheaval or elevation, when applied to scoriaceous and tufaceous submarine dejections,

respect to some of the dejections which surround the trachyte of Rocca Monfina, M. Scacchi suggests that several of the mounts may have been separate points of eruption, and possibly had not reference to the great central crater. All the trachyte of Ischia, he shows, must have been formed under submarine conditions, as sea-shells alternate with it up to 1500 feet in height. The craters which supplied the materials of the Campi Phlegræi arose, he conceives, in the sea, however their accompanying cones may have been raised into the atmosphere; and those felspathic tuffs of the Campania which are far removed from their original vents, were, he suggests, not formed under the sea, but upon pebble-beds formed by rivers (and great lakes?), after the partial emersion of the land.

merely because the latter have somewhere been emitted from volcanic vents, we should be forced to grant, that the formation of domes, circuses, and valleys of elevation in sedimentary deposits of aqueous origin, has not been occasioned by the action of plutonic heat or its accompanying gaseous forces. It is evident that the *somewhere* whence the volcanic submarine detritus has been derived, may in many cases be hundreds of miles distant from the deposit; since no one can limit the area to which currents will transport light scoriaceous and volcanic dejections.

For my own part, however, I deem it to be impossible to examine the most striking valleys of elevation in our own country, such as Woolhope and the Dudley Hills, and see how the strata of limestone in those beautiful ellipses are the more fissured by transverse cracks, the more they have been strained and bent, and then observe that such ellipses often run parallel to adjacent outbursts of plutonic rocks *which have broken up and thrown off similar strata*, and not be convinced, that such examples do in some measure illustrate the point at issue. Will any other explanation suffice to account for the shape and fractures of the Wren's Nest and the ellipses near Dudley, except that of intumescence due to the powers of heat connected with the vast diffusion of plutonic matter in that tract? I may be excused for asking those English geologists, who may doubt the efficacy of the interpolated igneous rocks to have produced these striking results, to read the chapters I have written on the subject*, and afterwards the memoir of Mr. Blackwell, of Dudley, which delineates the underground play of the igneous matter, and shows how it has powerfully fractured all the submarine strata and given to the Staffordshire coalfield its form and outline. It is scarcely fair to argue against all craters of elevation, because no plutonic or volcanic rocks have been observed to form the central fulcrum of our English valleys of elevation. For, in my mind, the very circumstance that such ellipsoids are so symmetrically eccentric in their dip, is the reason why we should not expect to find any igneous rock within them. It is, I suggest, from the repression of the effort of the heat, steam, and gases to escape upwards along the axes of such ellipsoids of elevation, that their quâ-quâ-versal arrangement is due. Nor must it be forgotten, that in the very districts so affected, the igneous matter has usually sought an issue (notably, for example, in the Rowley, Malvern, and Abberley Hills) along the edges of the adjacent deposits, probably because it there met with less resistance than in the neighbouring tracts, which deposits have by the same causes been rolled into undulations, or heaved up into rapid anticlinals. In numerous cases, however (and the west flank of the Malvern is a good instance), we see that the eruptive rock has performed the part of raising and even of overturning the strata on its flank.

The observations I made in Italy, and which I again apologise for, as being necessarily imperfect, have thus led me to add a few words to what I have already written† upon the subject, in the hope of mo-

* See Silurian System, pp. 480, *et seq.*

† See Silurian System (Valley of Woolhope).

difying the extreme views of the advocates for and against elevation-craters. Although much indebted to M. Leopold von Buch for suggesting the theory, to M. Élie de Beaumont for extending and illustrating it, and to Sir C. Lyell for his efforts to explain all these appearances by reference to causes now visible, still I must express my belief, that the truth which geologists are in quest of lies in neither extreme. I think, indeed, that the day is not distant when it will be admitted, that in some tracts, in which *submarine* volcanic dejections have been very widely diffused and carried to great distances from the orifices of eruption, the strata have since been heaved up eccentrically by the subsequent operation of heat and intumescence, whether accompanied by an actual eruption of molten matter and scoriæ or not. Such then must be considered craters of elevation. On the other hand, in reference to true volcanic *coulées* and detritus, some districts will be shown to abound still in those grand volcanos, which during countless ages have been augmenting their area by materials, which, derived from their own bowels, have been continually added to their flanks.

Postscript.

On writing to Dr. Daubeny for an explanation of his views, I find that on one essential point his opinion coincides with my own, viz. that the external dejections around Rocca Monfina *have been all formed under water*, perhaps of no great depth,—an opinion which I am glad I have elicited, as the most careful perusal of his memoir, in which he makes no allusion to subaqueous volcanic operations, had led me to draw another inference.

In the present state of geology, I hold it to be of the utmost importance to distinguish in a marked manner between subaqueous and subaërial volcanic action, and to note well, when it is possible, the cases where both operations have been united. It was to bring this point out in relief that the foregoing lines were penned.

February 27, 1850.

The following communications were read:—

1. *An Account of the* Strata and Organic Remains *exposed in the Cuttings of the Branch Railway, from the Great Western Line near Chippenham, through* Trowbridge, *to* Westbury *in Wiltshire.* By Reginald Neville Mantell, Esq., C.E.

[Communicated by G. A. Mantell, Esq., LL.D., F.R.S., G.S.]

This railway passes over the usual series of the oolitic deposits of that part of England, and in the distance of fifteen miles the cuttings brought to light immense quantities of fossil shells, remains of numerous species of Cephalopoda, trunks and branches of trees, and a few bones of reptiles.

Mr. Morris with his accustomed liberality and kindness has carefully examined the fossils collected by me in these cuttings, and also the rich collection of Mr. Macneil, of Trowbridge, and has drawn up the lists that accompany this paper, and which constitute its most important feature.

The subdivisions of the Oolite traversed by our operations were the following:

Portland Limestone, Kimmeridge Clay, (Coral rag wanting.)	in a cutting near Westbury Station.
Oxford Clay, Kelloway Rock, Cornbrash,	in a cutting in the neighbourhood of Trowbridge.
Forest Marble, Bradford Clay, Great Oolite,	occurring on a branch line, three miles long, to Bradford.

The Lower Greensand is exposed at Westbury Station.

The Wilts and Weymouth branch of the Great Western leaves the main line at Thingley, a village half way between Chippenham and Corsham, and takes a southerly course to Westbury, a distance of fifteen miles, where the line terminates at present.

At Thingley the rock exposed in the cuttings of the Great Western is the Cornbrash, which extends over a large area of the neighbouring country, including Chippenham. This rock appears in the Wilts and Weymouth cuttings for a mile and a quarter, and then, on the opposite side of a steep valley, rises rapidly and crops out; the remainder of the section, which is about 11 chains long and 20 feet deep, exposing the lower beds of the Cornbrash, and the marls and shales of the Forest marble. After crossing another high embankment, the Cornbrash reappears at the entrance of the cutting, dipping rapidly, and it is not again visible till we reach Trowbridge, nine miles and a half from the junction with the Great Western.

After losing the Cornbrash at the second mile, the line continues nearly the whole way to Staverton, at the seventh mile, on embankments, keeping along the valley of the river Avon. This valley is covered with a bed of gravel from 4 to 18 feet in thickness, and from half a mile to a mile and a half in width, and in it are found boulders and pebbles of numerous varieties of primary and secondary rocks, and rolled fossils of the Oxford clay and Kelloway rock. Mounds of the Oxford clay occasionally protrude through this accumulation of water-worn materials.

At Staverton the line crosses the river Avon, and leaving the valley, enters a series of cuttings in the Oxford clay and Kelloway rock, which extend to the 9½ mile, near Trowbridge. It was from these cuttings, averaging 14 feet in depth, that I obtained the greatest number of *Ammonites Kœnigi*, *Ancyloceras Calloviense*, &c.

At seven miles and a half the railway crosses the river Biss, where the Section fig. 1 commences.

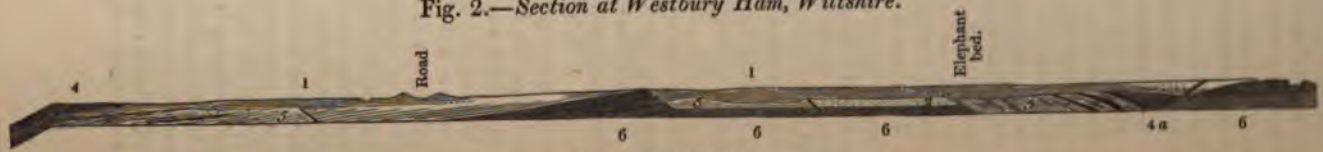
The Cornbrash reappears on the other side of the Biss, and the

Fig. 1.—*Section exposed by the Trowbridge Railway-cutting.*

Horizontal scale, 1 chain to $\frac{1}{15}$ inch. Vertical scale, 5 feet to $\frac{1}{15}$ inch.

1. Drift, 3 feet, with *Serpula vertebralis* and other shells from the Oxford Clay, and with pebbles of Cornbrash.
2. Oxford Clay.
   a. Bituminous slaty clay, with *Belemnites*, *Belemnoteuthis*, *Ammonites*, and *Rostellaria*. Septaria and veins of stone, the latter containing *A. Reginaldi*.
   2. Oxford Clay (continued).
   b. Blue clay, with a fossil tree in the portion overlying the Kelloway rock.
   c. Mottled clay, altered by atmospheric agency.
   d. Blue clay.
   e. Blue clay, with *A. Kœnigi*; and with shale near the surface containing *Trigonia costata*.
3. Kelloway Rock. Sand and sandstone.
4. Cornbrash. Brashy stone and soft bed, 4 feet; solid rock, 3 feet; with three species of Ammonites, and numerous shells.
5. Lignite, 6 inches to 1 foot, containing large and small trees.
6. Blue marl, with very few organic remains.
7. Forest marble. Limestone in patches, with minute *Ostreæ*.
8. Gravel.

Fig. 2.—*Section at Westbury Ham, Wiltshire.*



Scale, 100 feet to $\frac{1}{2}$ inch.

1. Drift. 2. Gravel. 4. Greensand; 4 *a*, greensand capped with gravel (3). 5. Portland Oolite. 6. Kimmeridge Clay, with occasional beds of limestone.

Trowbridge station-yard is excavated out of this rock. A slight fault runs across the line at the point where the booking-office now stands, and the same displacement is visible half a mile off on the side of the turnpike road to Bradford. The Cornbrash continues very level to about the middle of the next cutting, where a displacement of considerable extent brings down the Oxford clay, which continues only for 6 chains, where another fault replaces the Cornbrash, which dips south rapidly, so as to disappear almost immediately. The Oxford clay lies on the Cornbrash, and a few chains further on we find a stratum of sandstone and sand representing the Kelloway rock. This too extends but a short distance, and the next cutting at Studley (10 miles, 20 chains) brings to light the bituminous unctuous shales of the Oxford clay*. This excavation is about 13 chains long, and 23 feet at its greatest depth; from it I obtained beautiful specimens of *Belemnites* and *Belemnoteuthis*.

The whole thickness of the shales exposed by this cutting is about forty-five feet, and were we to restore them to their original horizontal position, we should have the following sequence, commencing with the beds that would be the uppermost of the series.

Two feet of drift, which covers the surface everywhere, in some places to the depth of six or eight feet,—and is sometimes difficult to distinguish from the decomposed Oxford clay, being of the same yellow colour. Contains a few elephant's teeth.

Three feet of crumbly shaly marl, containing *Serpula vertebralis*.

Five feet of shaly marl, with *Belemnoteuthides* in abundance.

Nine feet of very strong slaty clay, containing about midway a layer of pyritical Septaria and numerous *Belemnites*, *Belemnoteuthides*, and *Ammonites*.

Two feet of thinner slaty clay, with quantities of *Rostellariæ* and drift wood.

One foot of rock, in which the *Ammonites Reginaldi* chiefly occurred.

Five feet of thick slaty clay, containing *Belemnites*, *Ammonites*, and lignite: *Belemnoteuthis* rare.

Three feet of crumbly stone.

Two feet of very strong clay, with but a few fossils.

Five feet of thick slaty clay, containing *Belemnites*, *Belemnoteuthides*, *Ammonites Jason*, and lignite.

Ten feet more of clay was exposed, but being intersected where it cropped out, it was decomposed and crumbly from the effects of the atmosphere.

Lignite occurs in most of the beds, and frequently with *ostreæ* attached. In one place a flattened tree twelve feet long was used *in situ* for some time as part of a barrow-run; so little was its vegetable structure and its strength and tenacity impaired, though the tree must have been coeval with the extinct belemnites with which it was buried. Much of the wood, especially the curious bed of lignite

* This clay emits a brilliant gas when burnt, and I have frequently used it to illuminate my room.

under the Cornbrash, was sufficiently carbonized to be used as fuel by the workmen and poor of the neighbouring cottages. The coniferous structure was easily detected by the microscope. I did not find any cones or other seed-vessels, and but few vestiges of foliage, nor did I meet with traces of *Cycadeæ*, although these plants have been occasionally found at Swindon.

Emerging from this section at 10½ miles, and traversing a slight excavation at Yarnbrook (11½ miles) in the same shale, and some heavy cuttings in Kimmeridge clay, at 14 miles, we come to a very interesting section through the Ham Fields at the Westbury Terminus (see Section, fig. 2). Here a fault brings the greensand in contact with the Kimmeridge clay, and after four more displacements the greensand resumes its position, and forms the plain on which the Terminus is erected.

One of the depressions caused by a fault in this cutting is filled up by a deposit of bones belonging to elephants, horses, deer, and other quadrupeds: these remains were so plentiful that the workmen repaired the waggon roads with them. A well at the Station pierces the several beds, and enables us to continue the section half a mile further.

Organic Remains.

The abundance of fossils in some of the beds was truly astonishing, and especially the immense numbers of the shells and osselets of *Cephalopoda*. Often on exposing an area of clay or shale many yards in extent, the whole surface was studded with the glittering pearly shells of *Ammonites* of various species, and the numerous phragmacones of *Belemnoteuthis*, intermingled with *Belemnites*. With these relics of deep-sea molluscs were associated in equal abundance shells of the genera *Rostellaria*, *Turritella*, *Auricula*, &c., and throughout the mass, stems, branches, and fragments of pines and firs were imbedded. Groups of Ammonites scarcely larger than a pin's head, were often lying together as if they were clusters of the embryo shells, and Belemnites as minute as a small wire were not uncommon.

I had the good fortune to obtain a few Belemnites that showed the capsule of the guard, and the form of the peristome of the phragmacone; and likewise osselets of the *Belemnoteuthis* with the apical part of the phragmacone surrounded by its fibrous investment. These specimens have been figured and described by my father in the Philosophical Transactions. It may be interesting to remark, that although ink-bags in conjunction with the phragmacones of the *Belemnoteuthis* were very frequent, I never on any occasion found an ink-bag naturally attached to the phragmacone of a belemnite*.

In the subjoined lists of organic remains by Mr. Morris, the species and genera found in the respective strata are enumerated, and a

* I lately saw, in Dr. Warren's Collection, at Boston, U.S., a specimen, which might lead to an error with regard to this subject. It consisted of a belemnite with indistinct traces of the prolongation of the phragmacone, and on the top of it was loosely tied the ink-bag of a belemnoteuthis; the specimen being ticketed, "Belemnite with ink-bag, Oxford Clay, England."

few new species are named and described. The following abstract shows their distribution:—

Kelloway Rock	Radiaria,	3 genera.
	Conchifera,	16 genera, comprising 22 species.
	Mollusca,	5 genera.
Oxford Clay	Annelida,	1 genus.
	Conchifera,	5 genera.
	Mollusca,	several genera.
	—— Cephalopoda,	6 genera.
	Pisces,	2 or 3 genera.
	Reptilia,	4 genera.
Cornbrash	Radiaria,	3 genera.
	Conchifera,	8 genera.
	Mollusca,	1 genus.
Bradford Clay	Radiaria,	3 genera.
	Conchifera,	4 genera.

Thus it appears that from the small area of the bed of the Oolitic ocean exposed by the railway excavations, there were obtained above thirty genera of Conchifera, and seventeen of Mollusca, of which no less than eighteen species belong to Cephalopoda.

I will only observe, that the spectacle daily presented to my view, during the many months I was engaged on the construction of this railway, strongly impressed on my mind the conviction that I was exploring a mud-bank of an ancient ocean, to which terrestrial plants and trees, and the shells of littoral and shallow water species of mollusca, had been transported by currents, and promiscuously intermingled with the exuviæ of the inhabitants of the profound depths of the sea.

The characters of a fluvio-marine formation given by M. Constant Prevost seem particularly applicable to these deposits:—"Prédominance des sédiments alternativement argileux et arénacés régulièrement stratifiés; abondance de végétaux terrestres et par suite d'amas et de bancs de charbons; présence d'animaux fluviatiles ou terrestres associés dans les mêmes conches à des animaux marins. On peut ajouter que, dans les formations fluvio-marines pélagiennes, les argiles prédominent sur les grès, que les fossiles sont bien conservés, qu'ils sont isolés ou groupés avec ordre par familles et par lits, que les fossiles marins rappellent des animaux de haute mer; enfin l'absence presque absolue des Polypiers pierreux*."

List of Organic Remains obtained by REGINALD N. MANTELL, Esq. *from the Railway Cuttings above described.* By JOHN MORRIS, F.G.S.

Kelloway Rock.

RADIARIA.

Acrosalenia —— ?
Cidaris —— ?
Pentacrinus —— ?

CONCHIFERA.

Pholadomya Murchisoni, *Sow.*
—— acuticosta, *Sow.*
Panopæa (Pullastra peregrina, *Phil.* sp.).
Modiola bipartita, *Sow.*

* "De la Chronologie des Terrains et du Synchronisme des Formations," p. 5.

Isocardia tener, *Sow.*
—— minima, *Sow.*
Arca subtetragona, *Morris*, n. s.
Amphidesma ?? recurvum, *Phil.*
Nucula Phillipsii, *Morris*, n. s.
Trigonia clavellata, *Sow.*
Cardium cognatum, *Phil.*
Astarte carinata, *Phil.*
Pecten fibrosus, *Sow.*
—— demissus, *Phil.*
—— vagans, *Sow.*
Gryphæa obliquata, *Phil.*
Terebratula socialis, *Phil.*
—— concinna ?, *Sow.*
—— ornithocephala, *Sow.*
Corbula Macneillii, *Morris*, n. s.
Orbicula —— ?

MOLLUSCA.

Auricula Sedgvici, *Phil.*
Turritella muricata, *Sow.*
Rostellaria bispinosa, *Phil.*
Ancyloceras Calloviense, *Morris.*
Ammonites modiolaris, *Lhwyd*, sp.

Oxford Clay.

ANNELIDA.

Serpula vertebralis, *Sow.*

CONCHIFERA.

Avicula expansa, *Phil.*
Modiola bipartita, *Sow.*
Trigonia clavellata, *Sow.*
Nucula Phillipsii, *Morris*, n. s.
Ostrea deltoidea, *Sow.*

MOLLUSCA.

Turritella muricata, *Sow.*
Rostellaria.
Belemnites abbreviatus, *Mill.*
—— Puzosianus, *D'Orb.*
Belemnoteuthis antiquus, *Pearce.*
(Acanthoteuthis ?)
Loligo.
Sepia ? (Two species of).
Ammonites modiolaris, *Lhwyd*, sp.
—— Chaumussetii, *D'Orb.*
—— Kœnigi, *Sow.*
—— Jason, *Rein.*
—— cordatus, *Sow.*
—— Gowerianus, *Sow.*
—— Lonsdalei, *Pratt.*
—— Reginaldi, *Morris*, n. s.
Nautilus truncatus ? *Sow.*

PISCES.

Teeth of Lepidotus.
—— Sphærodus.
—— Pycnodus.

REPTILIA.

Ichthyosaurus.
Plesiosaurus.
Pliosaurus.
Cetiosaurus.
Teleosaurus ?

Cornbrash.

RADIARIA.

Nucleolites clunicularis, *Agass.*
—— orbicularis, *Phill.*
Discoidea depressa, *Lamx.* sp.

CONCHIFERA.

Pholadomya Murchisoni, *Sow.*
Panopæa (Mya) gibbosa, *Sow.*
—— ? (Pullastra peregrina, *Phil.* sp.)
Amphidesma ? decurtatum, *Phil.*
Cardium cognatum, *Phil.*
Isocardia concentrica, *Sow.*
Avicula echinata, *Sow.*
Ostrea Marshii, *Sow.*
Tereb. intermedia, *Sow.*
—— obovata, *Sow.*
—— concinna, *Sow.*

MOLLUSCA.

Ammonites discus, *Sow.*

Bradford Clay.

CONCHIFERA.

Avicula costata, *Sow.*
Pecten vagans, *Sow.*
Ostrea costata, *Sow.*
Tereb. coarctata, *Sow.*
—— digona, *Sow.*
—— maxillata, *Sow.*
—— obsoleta, *Sow.*

RADIARIA.

Berenicea diluviana, *Lamx.*
Terebellaria ramosissima, *Lamx.*
Apiocrinus Parkinsoni, *Bronn.*
(A. rotundus, *Miller.*)

AMMONITES REGINALDI, Morris.

PL. XXX. fig. 6.

Am. testâ discoideâ, inflatâ, anfractibus latis subdepressis, intus obliquè angulatis, 15–17 tuberculis prominentibus, externè costatis, costis obtusis, rotundatis, dorso convexo, aperturâ transversâ, semi-ellipticâ.

A discoidal and somewhat gibbose shell, with rather depressed and broad volutions, inner side obliquely angular, margined with about fifteen prominent rounded tubercles, from each of which arise two or three obtuse costæ passing over the broad convex back; these costæ become obsolete in an adult state.

Aperture transverse, semi-elliptical. Thickness 4½ inches, diameter 15 to 18 inches. This shell, in possessing the same general characters, may be considered by some as an extreme variety of *Am. coronatus*, Bruguière; it varies considerably in the size of the umbilicus and number of dorsal ribs; the latter become obsolete by age in this species, as shown in the adult specimen figured (reduced) by D'Orb. Terr. Jurass. t. 169. f. 5. It also bears considerable resemblance to *Am. Banksii*, Sow. M. C. tab. 200, and which is also cited by D'Orbigny as a variety of *Am. coronatus*. This shell, from the Oxford clay near Trowbridge, presents, however, a permanent and distinct variety in which the tubercles are more round and prominent and the volutions less angular than in the normal type of *Am. coronatus*.

The large knobbed species from the Lewes chalk named *A. peramplus* by Dr. Mantell (Fossils of the South Downs, p. 200. n. 60; Sow. Min. Conch. pl. cccl vii.), also bears a general resemblance to this species.

The specific name is to commemorate the industry and research of its discoverer.

Locality. In the Oxford clay near Trowbridge.

ASTARTE CARINATA, Phillips, Geol. Yorksh. t. 5. f. 3.

PL. XXX. fig. 2.

Ast. testâ crassâ, gibbosâ, ovato-triangulari, subæquilaterali, costis obtusis concentricis instructâ, interstitiis paulo latioribus; lunulâ ovatâ, profundâ; margine intus valdè crenatâ.

Shell ovately trigonal, ventricose, subequilateral, concentrically costated, costæ obtusely rounded; anterior margin rounded, posterior depressed and slightly truncated; lunule smooth, ovate, deeply impressed, inner margin strongly dentated.

Width rather more than length; length and thickness equal.

This species is considered to be identical with the *Ast. carinata*, Phillips, Geol. Yorksh. pl. 5. f. 3, although that figure does not well display the general character; it closely resembles the *A. vetula*, Philippi (Dunker, Palæontographica, t. 8. f. 3), from the tertiary beds of Cassel, but that species has the anterior margin more angular, and the lunule distinctly striated.

The intervening furrows are double the width of the costæ, and when carefully examined exhibit faint traces of concentric striæ.

Locality. Abundant in the Kelloway rock near Chippenham and Trowbridge, and the Oxford clay of Weymouth and Yorkshire.

Numerous casts of another species of *Astarte* (PL. XXX. fig. 3) are found in the Kelloway rock near Trowbridge, resembling the one figured by Phillips, Geol. Yorksh. pl. 5. fig. 30.

Corbula? Macneillii, Morris.

Pl. XXX. fig. 4.

Cor. testâ parvâ, ventricosâ, arcæformi, lævigatâ; subæquilaterali, anticè rotundatâ, brevi, posticè carinatâ, truncatâ.

Shell small, smooth (or faintly striated), ventricose, arcæform or somewhat quadrangular, nearly equilateral, anteriorly rounded, posterior side carinated, the carina extending from the umbo to the lateral margins, which are truncated and slightly produced.

This shell strongly resembles the *Corbula dubia*, Sow., and especially the *Corb. cucullæformis*, Dunker (Beiträge, p. 31. t. 2. f. 6), with which it so generally agrees that I should have considered it the same, were it not that the incurvation of the beak (represented in the figure) is somewhat different, and also that the shell is described as striated.

Compare also *Corbula borealis*, D'Orb. (Sir R. I. Murchison's Russia, t. 41. f. 5–7).

The hinge not having been seen, this shell is placed in *Corbula* with some doubt, as it more nearly resembles some forms of *Isocardia* and *Cypricardia*.

Dedicated to Mr. Macneill of Trowbridge, who has materially increased our knowledge of the fossils of that vicinity.

Locality. Abundant in the Kelloway rock near Chippenham and Trowbridge.

Nucula (Leda) Phillipsii, Morris.

Pl. XXX. fig. 1.

Nuc. testâ transversâ, subovato-trigonâ, lævigatâ, inæquilaterali, subventricosâ, margine cardinali angulatâ.

Shell ovately trigonal, smooth, inequilateral, slightly ventricose, posterior margin rather produced, but not recurved.

The abrupt manner in which the lateral margins meet the rounded anterior margin appears to be a character of this species; it might be compared with the *N. nuda*, Phillips, Geol. Yorksh. pl. 5. f. 5, but that shell is more transverse and inequilateral.

Locality. In the Oxford clay near Trowbridge.

Arca subtetragona, Morris.

Pl. XXX. fig. 5.

Arca testâ ovato-quadratâ, ventricosâ, inæquilaterali, sublævigatâ, latere anteriori brevi, posteriori carinato; areâ ligamenti rhomboidali.

Shell ovately quadrangular, ventricose, nearly smooth, or marked with shallow concentric striæ; the sides with small radiating costæ, more prominent on the anterior part than the posterior; posterior side strongly carinated; ligamental area shallow, lozenge-shaped, striated; umbones prominent, distant, involute. This shell somewhat resembles

Fig. 1. 1 a. Nucula Phillipsii.—Fig. 2. a—e. Astarte carinata. Fig. 3. Astarte ?
Fig. 4. a. c. Corbula Macneillii.—5. a. b. Arca subdecussata.—6. Inoceramus Vergoldii.
The figures marked X. are magnified.

Cucullæa inflata, Römer, but the umbones are not so prominent, and the posterior angle is more acute.

Locality. Kelloway rock, near Trowbridge.

EXPLANATION OF PLATE XXX.

Fig. 1. Nucula Phillipsii.
Fig. 2. Astarte carinata.
Fig. 3. Astarte?
Fig. 4. Corbula Macneillii.
Fig. 5. Arca subtetragona.
Fig. 6. Ammonites Reginaldi.

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2. *Notice of the Remains of the* DINORNIS *and other Birds, and of* FOSSILS AND ROCK-SPECIMENS, *recently collected by* Mr. WALTER MANTELL *in the* MIDDLE ISLAND *of* NEW ZEALAND; *with Additional Notes on the* NORTHERN ISLAND. By GIDEON ALGERNON MANTELL, Esq., LL.D., F.R.S., G.S. &c. *With Note on* FOSSILIFEROUS DEPOSITS *in the* MIDDLE ISLAND *of* NEW ZEALAND. By Prof. E. FORBES, F.R.S. &c.

THE remoteness of New Zealand, and the long period required for the transmission of specimens to England, together with the very limited information we at present possess of the geology and palæontology of that interesting antipodean colony, impart a certain degree of importance to any accession of knowledge, however slight, relating to the physical structure, and the ancient fauna and flora of those distant islands.

These considerations induce me to submit to the Society the following remarks on a large collection of the bones of several species of Dinornis and other birds, of rock-specimens, and of fossil shells, corals, and infusoria, received a short time since from my eldest son, Mr. Walter Mantell, of Wellington; and although the information afforded by this collection respecting the geological structure of the country is but scanty, I would fain hope that this brief communication will not be deemed an uninteresting supplement to the memoir on the Fossil Birds of New Zealand, which I had the honour to lay before the Geological Society in 1848.

The specimens were accompanied by numerous sketches of the country, and a copy of the official report on the colonial capabilities of the eastern coast of the Middle Island, from Kaiapoi to Akaroa in Banks' Peninsula, and thence to the Scotch settlement at Otago, a distance of about 260 miles, made during my son's exploration of that tract in 1848, as Government Commissioner for the final settlement of native claims.

Such parts of this report as throw light on the geology of the Middle Island of New Zealand, together with remarks on any particular locality, are embodied in the following extracts. As an apology for the brevity of his notes, my son dwells on the arduous character of a pedestrian journey through a country but very thinly inhabited; the engrossing nature of his official duties, and the limited time

allowed him, in the most unfavourable season of the year, for the accomplishment of the object of his mission. Premising, therefore, that the route was restricted to the sea-coast, diverging inland only when the depth and force of the streams that empty themselves into the sea rendered their passage dangerous, and compelled a detour to a more narrow or shallow part of the river-channels, and that no leisure was permitted for the accurate investigation of geological phænomena, I proceed without farther comment to the extracts from my son's note-book: I will afterwards briefly describe the specimens of rocks and organic remains, and conclude with a few general observations on the facts submitted to the consideration of the Society.

Fig. 1.—*Sketch of the Geology of part of the Eastern Coast of the Middle Island of New Zealand. By* WALTER MANTELL, *Esq.*

Extracts from Mr. Walter Mantell's Notes.—"Banks' Peninsula, in the centre of the east coast of the Middle Island of New Zealand, is chiefly composed of a group of mountains of igneous origin, apparently the result of submarine eruptions. The two principal harbours, namely Port Cooper (now called Port Victoria), and Port Levi (now Port Albert), are separated by a lofty range almost destitute of wood; along the crest of this range metamorphic rocks crop out, dipping eastward, whilst on the opposite side of Port Cooper they incline at a considerable angle to the west.

"From the summit of a hill at the south-west angle of this Peninsula, a magnificent view is commanded of those extensive plains which stretch from the Double Corner, a headland north of Port Cooper, to Te Timaru, a distance of 130 miles. Below is seen the dreary 'Ninety-mile Beach,' which is a continuous line of shingle without bay or headland. Within the northern part of this shingle-bank is the lake Waihora, which is eighteen miles in length. In the middle distance, plains of vast extent stretch out, and are bounded by that part of the snowy mountains, now called the Wakefield range. The level country consists of a substratum of slightly coherent gravel, principally composed of pebbles of schist, jasper, and white, yellow, pink, and green quartz, covered by a layer of rich loam, which varies in thickness from a few inches to ten feet. These magnificent plains extend uninterruptedly from thirty miles north of Port Cooper to 100 miles south of it, having an average breadth of thirty-five miles. From the sea-shore to the ridge of high mountains covered with perpetual snow, a gentle rise only is perceptible; but it is probable that near the foot of the mountains the elevation of the plain above the level is not less than from 350 to 400 feet: there is likewise a slight rise to the south, for at Te Taumutu the land is but eight or ten feet above the sea-level, while at Hakatere it is at least from thirty to forty feet.

"Along the junction of the plain with the Peninsula there are many isolated sand-hills; and farther north, the river Waimakariri near its mouth cuts through a bed of finely laminated sand, under which, at a depth of about ten feet, there is a deposit of various kinds of wood, that appears to have been drifted down when the mouth of the stream was some miles inland of its present position, and the Peninsula an island, and the plain covered by forests, of which a few vestiges only remain. A similar deposit of wood is said to exist near where the Waikirikiri discharges itself into the Waihora. Should future examination prove that these vegetable accumulations have been drifted to their present sites, and not have resulted from forests that grew on the spot, it may be inferred that Banks' Peninsula has but recently been united to the main land, and that the western shore of the lake Waihora formed, at no very distant period, part of a bay of the sea.

"The wood from the above localities is so little changed, as to serve for fuel to the natives of the neighbouring district. It has the usual appearance of the drifted trunks and branches that are stranded on the beach, and burns in the same mouldering manner*.

* "The natives informed me, that at a day and a half's journey inland of Tau-

"The rivers that intersect the plain are generally rushing torrents, which have excavated deep channels; they mostly terminate in a lagoon, separated from the sea by beach: through this barrier of shingle some of the streams periodically burst, but others always discharge themselves by filtering through the bar. The water of a river on whose bank we were encamped, and which was completely blocked up by a dam of beach twenty feet high, fell two feet during the night.

"The Waihora and some others of the lagoons are opened periodically by the natives, for the purpose of capturing the fish with which these waters abound. Numerous narrow trenches are cut, and as the water gushes out, nets are spread, and eels, &c. caught as they are carried down by the stream. A trench about two feet wide will yield some hundreds of eels, three or four feet long, in a single day. In a short time the rushing waters wear away the intervals, unite the trenches, and scour away the entire barrier; the lake rapidly sinks to the sea-level, and leaves dry a tract from a quarter to half a mile in breadth; the tide then ebbs and flows into the bay, till a southerly gale drifts in the sand and shingle, and the bay is again converted into a lagoon. Each of the largest rivers has an extensive denuded tract at its mouth, commencing a mile or two inland, and gradually widening towards the sea; and this is intersected by flood-channels. These triangular delta-like areas are bounded by cliffs, and have evidently been produced by the wearing down of the table-land nearly to the sea-level.

"From Rakaia to Wakanui the water from the interior finds its way through the gravel bed, and by undermining it, has formed along the sea-board innumerable chasms and gullies, which are yearly increasing in depth and length: the country here has no other drainage. Some of these gullies or subterranean courses are from one to two miles long; and it seems probable that many of the now open river-channels of the plain have originated in this manner.

"Scattered here and there in the immediate subsoil of these extensive plains, bones of the larger species of Moa have occasionally been found: I could not ascertain that any had been observed in the more ancient diluvial deposits; but I believe that, sooner or later, the swamps and river-beds will yield a rich harvest of these interesting remains.

"At about ten miles south of the Waiteruaiti the plain ends in the undulating country of Timaru*.

"The superficial deposits of Timaru are of the same nature as those of the plains, and are superposed on a vesicular volcanic rock, which

mutu there is coal in constant ignition, and that they are in the habit of procuring fire from it when they travel that way. In the Chatham Islands a bed of burning peat or lignite is also said to occur; a native of Taumutu, who had seen it, said the substance burning on the plain was very different."

* "About ten miles inland of *Arowenua*, the *Kāurĕke*—the only native quadruped besides the field-rat in which we have any reasonable grounds for believing—is said still to exist." My son gives a long account of the appearance and habits of this unknown quadruped, derived from the most intelligent natives, but which would be foreign to the present notice.—G. A. M.

reaches a height of fifteen feet, and, gradually dipping to the south, disappears in the course of a few miles. The country then resumes its former aspect, save that instead of one vast continuous tract of level land, there are small narrow plains intersecting gently-undulating downs.

"A bed of coal, ten feet in thickness, is said to crop out on the bank of a stream inland of Timaru. Specimens were obtained from this locality by Mr. Torlesse; it resembled the lignite from Mount Grey, but was more bituminous.

"Striking from the coast across a plain about four miles wide, forming the north point of the Waitaki valley, we reached Te Morokura. The river, a torrent with a freshet channel half a mile in width, cuts through the gravel of the plain, which in the river-bed is intermingled with basaltic and porphyritic pebbles, brought down from the interior of the country by the stream. On the south side the plain is bounded by the Pukehuri range, a spur from the Southern Alps, about 1000 feet high, composed of highly-inclined strata of slate, covered by a ferruginous conglomerate of quartz pebbles.

"In Awaamoko, the next transverse gulley west of Waikoura, I observed beds of slate with veins of quartz, dipping south 70°; but I could not, in my rapid passage, make out the relative position of these slates and the quartz conglomerate in the next valley, east of Waikoura, by which we left the Waitaki plain.

"Beyond Morokura the country of Waiareka commences, and strata of a yellow and fawn-coloured limestone appear, and continue to Kakaunui. This limestone is generally friable and porous; it almost wholly consists of shells and corals, and contains terebratulæ, echinites, a species of pseudo-belemnite, teeth of sharks, &c. A microscopical examination shows that the calcareous cementing material of the larger shells and corals is made up of Textulariæ, Rotaliæ, and other common genera of Foraminifera, as will be particularized in the sequel.

"The beds are gently inclined and in various directions; a section north and south at the low caves at Te Anaamatara, where the last traces of these deposits were visible, showed a slight dip to the north.

Fig. 2.—*Caves in the Limestone at Te Anaamatara.*

"This limestone, both at Ototara and Te Anaamatara, is very cavernous; and two large caves at the former place afforded a comfortable night's lodging to myself and my companion, Mr. Alfred Wills, and our party; and it was no small gratification to me to collect from the walls of our cavern the next morning, terebratulæ, shark teeth, and other fossils, which, if not identical with, seem closely allied to, those I used to obtain, when a lad, from the chalk near Chichester; and which now seeing again for the first time since I left England nine years ago, appeared like old familiar faces greeting me from the rocks of the Antipodes.

"I had no opportunity of ascertaining the relative position of this formation, and the volcanic grit of Kakaunui: the latter on the coast is exposed to the height of eight or ten feet, and dips to the south at a considerable angle; it contains a great variety of crystalline volcanic products, as hornblende, augite, garnets, &c. It is covered unconformably by the usual diluvial beds of gravel and clay, as in the annexed sketch.

Fig. 3.—*Section of the Coast at Kakaunui.*

Clay without organic remains.
Diluvial gravel, consisting chiefly of quartz, trap, amygdaloids, &c.
Volcanic grit.
The sea beach.

"A mile south of Kakaunui, strata of a tertiary blue clay first appear; they contain numerous shells of species that inhabit the neighbouring sea, corals, a few traces of fishes, and small portions of wood. In some localities the clay is capped by a thin layer of sandstone.

"The following section of the coast will show the relative position of this tertiary clay.

Fig. 4.—*Section of the Coast near Kakaunui Point.*

1. Diluvial clay. 2. Gravel. 4. Blue clay with shells.
3. Indurated sandstone with shells. 5. Volcanic grit, at Kakaunui Point.

"Midway between the Bluff and Moeraki, the clay contains layers of septaria, varying from one to five feet and more in diameter. Hundreds of these nodules, which had been washed out of the undermined clay cliffs by the encroachment of the sea, were scattered along the beach, as represented in the sketch, fig. 5. Some were subglobular,

Fig. 5.—*Onekakara Bay, looking northwards.*

1. Diluvial clay.
2. Gravel.
3. Tertiary clay.
4. A group of Septarian boulders, called by the whalers the "Ninepins."
5. The White Bluff.

others spherical; many were entire, whilst others were broken, and glittering with yellow and brown crystals of calcareous spar, with which all the interstices of the septaria were lined or filled. Some of these masses were hollowed out by the action of the waves into regular basins, which at low-tide stand up from the sands full of water, and are three or four feet deep, forming excellent foot-baths for the weary pedestrian.

"Many of these septaria struck me as curious from the zone or belt of cone-in-cone clay with which they were encircled, as in the subjoined sketch (fig. 6), which represents the usual form and appearance of one of these zoned nodules.

Fig. 6.—*Septarium with a zone of Cone-in-cone Clay.*

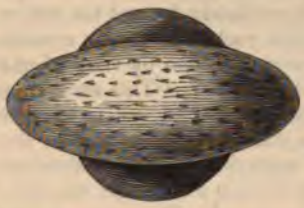


Fig. 7.—*Section of a Septarium, from Onekakara.*

a, *a*. Spherical body of the Septarium.

b. Fragment of bone imbedded in the Septarium.

"Fig. 7 is a section of the same, exhibiting the cone-like structure. The direction of the apices of the cones is towards the centre of the nodule; the coating of the other part of the sphere (fig. 6, *a*, *a*) is composed of clay with crystals of selenite; the cones are represented disproportionately large, to render the structure intelligible. These septaria, with the exception of the belt of cone-in-cone clay, are so like those I recollect seeing extracted from the London clay off the coast of Sussex, and used for Roman cement, that I think they may be applicable to the same economical purpose. I gave some to Capt. Collinson, R.E., who had it burnt and ground by a mason, who pronounced it worthless; but I still put faith in my cement, and not in the lime-burner*.

* A portion of one of these nodules has, through the kindness of Sir Henry De la Beche, been analysed at the laboratory of the Museum of Practical Geology;

"In one of these septaria I perceived the fractured end of the portion of bone enclosed (fig. 6, *b*); it ran straight into the mass, which was two feet in diameter. This fragment of bone is flattened, and is 1½ inch in its longest diameter; its cancellated structure appears to me to resemble that of the Moa: as it is the only vestige of a fossil bone I have found in the ancient tertiary strata of New Zealand, I hope you will deem it interesting*.

"At Onekakara, strata of a green gritty marl, much contorted, and in some places almost vertical, crop out from beneath the blue clay; these are traversed here and there by veins and layers of nodules of iron pyrites. The water which flows from these beds is highly saline and chalybeate, and of course extremely nauseous; but as no better can be obtained within a considerable distance, it is constantly used by the natives at the Kaika for domestic purposes.

"On the south, immediately beyond the native settlement at Moeraki, a dark porphyritic rock with broken crystals of felspar appears; it is traversed in every direction by veins of quartz and chalcedony, often very beautifully coloured. This rock continues to the end of the native Reserve at Waimataitai, where the tertiary blue clay again emerges, and forms the low cliffs of Katiki Bay. In the bight of this bay the bed of septaria previously described reappears; the nodules in this locality contain a far larger amount of iron and less lime than those before mentioned. The space at the foot of the cliffs left bare at low water was literally covered by septaria of various sizes, from a few inches to thirteen feet in diameter. The spot is known to the whalers by the name of '*Vulcan's foundry*.'

"I much regret that it was out of my power to leave the inland path from Katiki Bay to examine Matakea Point, where good coal is said to occur; but a smith at Onekakara, who had tried it, informed me, it was so sulphurous, that he was obliged to discontinue its use.

"Before reaching 'Pleasant River' I again traversed the beach for

and the results confirm the opinion that the New Zealand septaria will afford excellent cement.

Carbonate of lime	66·7
Silica	16·2
Alumina	10·4
Peroxide of iron	4·7
Organic matter	2·0
	100·0

estimated without water; of which, when sent, it contained two per cent.—G. A. M.

* The external form of this fragment conveys no idea of its nature; but slices carefully prepared for the microscope, present, under a moderately magnifying power, a structure which shows that the bone belonged to a bird; there is however no proof that it can be referred to the Dinornis. Mr. Tomes and Mr. Bowerbank, who have obliged me by examining the specimen, concur in this opinion. Insignificant as this fact may appear, still, in these early pages of the palæontological history of our antipodean colonies, it is worthy of remark, that the first-discovered fossil relic of the terrestrial vertebrata in the tertiary strata of New Zealand should belong to that class which, in later periods, constituted the principal types of the warm-blooded animals of the fauna of that country, to the almost entire exclusion of the mammalia.—G. A. M.

some distance, and found the cliffs were composed of the blue tertiary clay. The hills inland seemed to belong to the same age (clay-slate) as the Pukehairi range at Waitaki.

"At Waikouaiti, seventeen miles north of Otago, I found Mount Watkins to belong to the same class. Dikes of columnar trap, the columns at right angles to the sides of the veins, occur at Island Point, the Bluff, and Brinn's Point. These dikes traverse a deposit of pale buff-coloured sandy clay, distinctly stratified, and dipping about 40° to the south-west.

"In the little bight south of Island Point, in front of the native Kaika, named Makuku or Waipipipaika, is the exposed part of the so-called 'turbary deposit,' whence bones of the Moa have been obtained in such numbers and perfection. This bed is about three feet in depth, and not more than 100 yards in length, and lies immediately on the tertiary blue clay; it is visible only at low water. It consists almost wholly of decayed vegetable matter, and its surface is studded with the undisturbed roots of small trees, which appear to have been burnt down to the ground at some remote period. It is a light sandy elastic earth, of a blackish brown colour, emitting a strong fetid odour when first collected. From the large quantity of flax fibres (*Phormium tenax*) it contains, I conceive it was originally a swamp *.

"At Blueskin and Purakaunui Bays, the primary country of Otago begins, and boulders of serpentine of various shades of green are plentifully scattered on the sand-hills around Purakaunui. These bays afford an interesting illustration of the manner in which the harbours are gradually filled up when they are situated in a curve of the coast, and are exposed to a prevalent wind, and unprovided with a river having a current of sufficient strength to keep open a serviceable channel. Like Otago, each has a dry sand-spit running from its western nearly to its eastern head, that has been formed by the joint action of the sea and the land drainage: this constitutes a barrier, behind which the detritus brought down by the inland streams from the mountains tranquilly subsides, and eventually accumulates into a sand flat, through which the water flows into the sea. Blueskin Bay lying in the very bight, is the nearest advanced towards this state, to which Purakaunui and other similarly situated bays are rapidly tending."

I proceed to the examination of the specimens of rocks, minerals, and organic remains, collected by my son during the journey, and which are now in my possession.

Rocks and Minerals.

The collection contains between 200 and 300 specimens. With the kind and able assistance of Prof. Tennant, I have carefully examined such as seemed likely to prove interesting in an economical point of view; but a very general notice will suffice for my present purpose. They are chiefly pebbles and boulders from the line of

* Further remarks on this deposit will be given in another part of this notice.

coast traversed by the exploring party, with examples of the rocks and strata exposed in the low cliffs in the various localities mentioned in the report.

By far the greater part belong to plutonic, volcanic, and metamorphic rocks: the unaltered sedimentary deposits are limited to the limestones of Ototara and Anaamatara, the argillaceous strata of Onekakara and Kakaunui, and the newer beds of aggregated iron-sand and sandstone containing recent species of shells. Of the igneous products, the most abundant are *obsidian* (called by the natives *tuhua*), basalt, and many varieties of amygdaloids; some of these could not be distinguished from the toadstones of Matlock and Crich Hill, in Derbyshire. Nephrite or jade (*ponamu* of the New Zealanders), gneiss, serpentine, greenstone, chlorite slate, micaceous schist, siliceous slate, clay-slate, &c. There are no specimens of granite.

Sulphate of barytes, compact zeolite, and garnets; many varieties of chalcedony, agates, quartz, and jasper; some masses resemble the green or chlorite jasper of India; semi-opal, onyx, &c. There are no examples of any of the ores of tin or copper. Of iron, there are clays largely charged with oxide, sulphuret, and phosphate. Titaniferous iron (*menaccanite*) forms, with crystals of augite, extensive beds of sand on the shore of the North Island, near New Plymouth, &c. This sand constitutes the bed in which the bones of the Moa, &c. occur, near the embouchure of the Waingongoro, as mentioned in my former Memoir.

To this list may be added a fine white rock, resembling the meerschaum-stone, and consisting of carbonate of magnesia.

A very hard conglomerate of small pebbles of variously coloured quartz, jade, &c., cemented together by a ferruginous paste, is worthy of remark, from its close resemblance to the matrix in which diamonds occasionally occur in some parts of the Brazils.

A few fragments of lignite, and of bituminous wood, are the only indications of fossil fuel: no true coal, nor strata that are carboniferous in other countries, were observed in any part of the island comprised in the present notice.

Sedimentary Deposits and Organic Remains.

Ototara Limestone.

Of the stratified fossiliferous deposits, the most ancient is the limestone which stretches from near Morokura to beyond Anaamatara, and within five miles of Kakaunui. From the general lithological resemblance of this rock to the coralline cretaceous deposits of Faxoe and of Maestricht, and the presence of terebratulæ, sharks' teeth, echinites and spines, and fossils allied to the belemnite, the geologist might naturally conclude that the Ototara strata are referable to the chalk formation, and may be regarded as the equivalents of certain upper beds of the series. The microscopical examination would still further strengthen this idea, the Foraminifera of which the calcareous cement is almost wholly made up, belonging to those forms which prevail in the English chalk; even the soft bodies of

these animalcules are preserved in many instances, as in our cretaceous deposits. But I do not think that the facts are sufficient to warrant a decision, as to whether the strata in question should be considered as secondary or tertiary, for there are many eocene beds in which the organic characters are very similar: however this may be, these deposits are the most ancient unaltered sedimentary in the country under survey, of which specimens have been transmitted to England. A list of the fossils collected is subjoined.

I would here express in the warmest manner my obligations to Mr. Morris, for his kindness in determining the characters of many of the organic remains given in the following pages; and to Mr. Lovell Reeve, for the comparison of the shells with recent species; and to Mr. Williamson, and especially to Mr. Rupert Jones, for assisting me in the determination of the Foraminifera and Diatomaceæ. In the attempt to name with precision the organisms imbedded in the strata of our Antipodes, I gladly availed myself of the knowledge of those scientific friends who were most conversant with the respective subjects, and I now gratefully acknowledge the liberality and kindness with which at all times they afforded me their valuable aid.

Fossils from the Ototara Limestone.

Scales of fishes. (No specimens were sent to me.)

Teeth of a species of Shark, *Lamna*: Pl. XXVIII. fig. 1.

Belemnite? Fragments of a solid, subcylindrical, calcareous body, with a fibro-radiating structure, closely resembling that of the guard of the Belemnite: it is very like a fossil from the cretaceous beds of Pondicherry in India, described by Prof. E. Forbes as *Belemnites? fibula* *.

Terebratula. Fragments of a large smooth species.

—— *Gualteri*, nov. spec.: Pl. XXVIII. figs. 2, 3. "Shell somewhat trigonal, smooth, both valves nearly equal and rather depressed; lateral margins sinuous; rostral valve with an acute and slightly recurved beak, the perforation below it. The anterior margin with a broad sinus, producing a corresponding arched elevation in the smaller valve.

"This shell bears a remarkable resemblance to the *Terebratula subplicata* (of Dr. Mantell, Fossils of the South Downs, pl. 26. fig. 5), but may be readily distinguished by a careful comparison of the two species: in this shell there are no plicæ. I have named it *Gualteri* in honour of the discoverer, Walter Mantell, Esq."—*Mr. Morris.*

Pollicipes. Resembling a cretaceous species.

Cidaris. Fragments of plates and numerous spines.

Eschara. Pl. XXVIII. fig. 8. Investing *Cereoporæ.*

Cereopora Ototara, nov. spec.: Pl. XXVIII. figs. 4–7. This coral more closely resembles the *C. disticha* of Goldfuss, than any other known species. The cells, however, are more distinct and less regular. I propose to distinguish it by the name of the locality in which it was first noticed.

* Transactions of the Geological Society, 2nd Series, vol. vii. p. 119. pl. 9. fig. 3.

Cereopora: Pl. XXVIII. figs. 9–11. This species is nearly allied to *C. diadema* of Goldfuss.
Manon: Pl. XXVIII. figs. 12–14. A small claviform species.

Foraminifera.—With the exception of spicula of *Alcyonia* or *Gorgoniæ*, all the microscopic organisms belong to a few genera of Foraminifera. These have been carefully examined and compared by Mr. Rupert Jones.
Rosalina lævigata, Ehrenberg. Found in the chalk of Sicily.
—— *Beccarii*, Linn. sp. A common recent form.
——. Somewhat resembling *Cristellaria propinqua*, Reuss, from the tertiary formations.
Textularia: Pl. XXIX. fig. 1. "Nearly related to an undescribed gault species, and to a species from the magnesian limestone, *T. cuneiformis*, Jones."—*Mr. R. Jones.*
Textularia elongata, nov. spec.: Pl. XXIX. fig. 2. This is a remarkable species, and is so like a common but undescribed form in the Charing chalk-detritus, first discovered by Mr. Harris, that Mr. R. Jones thinks it is identical *.
—— *globosa*, Ehrenb. Common in the chalk.
—— *aciculata*, Ehrenb.: Pl. XXIX. fig. 3. Common in the chalk.
In addition to the above, Mr. R. Jones has detected the following:
Globigerina.
Nodosaria limbata, D'Orbigny. Cretaceous.
Cristellaria rotulata, Lamarck, sp. Cretaceous.
Dentalina.
Polymorphina.
Bulimina. Two or three species.
Rosalina Lorneiana, D'Orbigny. Cretaceous.

Entomostraca.—*Bairdia subdeltoidea*, Münster, sp. Recent, tertiary, and cretaceous.
Cythereis interrupta, Bosquet, sp. Cretaceous.
—— *gibba*, Rœmer, sp. Tertiary.
—— *galtina*, Jones. Cretaceous.

Pleistocene or newer Tertiary Blue Clay of Onekakara.

The argillaceous strata extending from near Kakaunui to Matakaea, abound in shells of species that still inhabit the neighbouring sea, and must therefore be considered as a comparatively modern tertiary or pleistocene formation.

The microscopic organisms are but few; they consist of circular discs with regularly perforated hexagonal apertures (*Coscinodiscus*), resembling a form common in the slate of Jutland; and others with a hyaline centre surrounded by a richly sculptured margin (*Actino-*

* I am doubtful whether this fossil does not terminate apically in a discoidal involution; thus resembling, in external form, the Spirolinites and Lituolites, but differing from the latter in the alternate arrangement of the cells. Specimens in flint, having this form and structure, have been transmitted to me by Mr. Samuel Smith, of Wisbeach.

cyclus). There are many sponge spicula traversed by a central tube, and other spines, apparently of *Alcyonia* or *Gorgoniæ*. The clay contains also fragments of a delicate branched body, having linear rows of regularly disposed openings. I have not observed any traces of *Foraminifera*, though my son mentions having found *Spirolinites*.

Bone of Bird: in a septarium (*ante*, p. 325).

Corals.—*Eschara*: Pl. XXVIII. fig. 8.

Pustulopora Zealandica, nov. spec.: Pl. XXVIII. figs. 20, 21. It is a beautiful species, allied to *Cereopora madreporacea* of Goldfuss.

Turbinolia: Pl. XXVIII. figs. 18, 19. There are two lamelliferous corals, apparently of this genus. One is of an inverted conical shape, fig. 19 *a*, the other has a broad, nearly flat, callous base, as shown in fig. 18.

Mollusca.—The shells are for the most part in a beautiful state of preservation, differing but little from dead recent specimens, except in being destitute of colour. With the assistance of Mr. J. E. Gray, Mr. Lovell Reeve, and Mr. Morris, the following genera and species have been determined:—

Turritella rosea, Quoy: Pl. XXVIII. figs. 16, 17.

Struthiolaria straminea, Sowerby. This genus is peculiar to New Zealand.

Triton Spengleri, Lamarck.

Fusus australis, Quoy. "Near to *F. sulcatus*."—*Mr. L. Reeve.*

—— *nodosus*, Martyn, sp.

Pyrula. Natica.

Ancillaria australis, Sowerby. "This fine species is very like one described by Mr. Hinds in the 'Mollusca of the Voyage of the Sulphur.' Among fossil shells it comes nearest to *A. glandiformis*, from Bordeaux, but is certainly distinct from it. Being found in the same semi-fossil state with *Struthiolaria* and *Triton Spengleri*, it probably exists on the neighbouring coasts*."—*Mr. Lovell Reeve.*

Calyptræa.

Dentalium; an undescribed, finely striated species: Pl. XXVIII. fig. 15.

Cardium. Nucula. Limopsis. Pectunculus, resembling the common Bognor species.

Arca. Pecten. Ostrea.

Mytilus. A beautiful striated recent species.

Vegetable remains.—Fossil wood of the Araucarian type, in which the internal structure is exquisitely preserved, and a fragment of a silicified monocotyledonous stem, are the only examples transmitted to me from these deposits.

* In a note on the Fossil Shells of New Zealand in Dr. Dieffenbach's work, vol. ii. p. 296, Mr. J. E. Gray mentions "an Ancillaria with a very callous apex," which is probably the same species.

Blue Clay of Wanganui, in the North Island.

In my former Memoir on the Fossil Birds of New Zealand, a bed of clay abounding in marine shells was described as underlying the bone-deposit *. A few specimens from this locality were sent in the present collection; they are in the same condition as the shells of Onekakara, and the stratum whence they were obtained is evidently of the same age; they are all of species existing in the South Pacific Ocean:

Fusus nodosus, Quoy.
Murex Zealandicus, Quoy.
Venus mesodesma, Gray.
Venericardia Quoyii, Lamarck.
Pecten asperrimus, Lamarck.

Infusorial Earth of Taranaki.

Along the shores of the North Island, and especially within a short distance of New Plymouth, there are extensive low mounds or hills of a siliceo-calcareous sand, of a light fawn colour, and which in some places is aggregated into concretionary friable masses. This deposit is in a great measure composed of the siliceous shields or frustules of *Diatomaceæ*, those vegetable structures which Ehrenberg considered of animal origin, and described as Infusoria. From the many forms similar to those so universally present in marine and brackish water deposits, I have selected a few which are delineated in Pl. XXIX., to convey an idea of the organic composition of this earth.

Stauroneis Zealandica, nov. spec.: Pl. XXIX. figs. 4, 5. This beautiful organism is very like a species from the "Little Falls," State of New York, but differs in the form of the shield, which is subangular in the middle, and in the central bar or cross; I have therefore given it a specific name.

Surirella: Pl. XXIX. figs. 6, 7. "Resembles *S. bifrons*, Ehrenb." —*Mr. R. Jones.*

Navicula librile, Ehrenb.

Pinnularia: Pl. XXIX. fig. 8. Mr. Topping informs me that the same form occurs in the Thames at Tilbury Fort.

Cocconema. "Resembling *C. cymbiforme*, Ehrenb."—*Mr. R. Jones.*

Actinocyclus: Pl. XXIX. figs. 9, 10.

Bacillaria. *Polycystina*: Pl. XXIX. fig. 11.

Eunotia ocellata, Ehrenb.

Pyxidicula or *Posodira*: Pl. XXIX. fig. 10.

Coscinodiscus.

Mr. Williamson of Manchester informs me, that in addition to the bodies I have detected, he has obtained from the earth I transmitted to him, *Polycystineæ* apparently identical with species that are abundant in the well-known infusorial earth of Barbadoes; and disks of *Meloseira*†.

* See Quarterly Journ. Geol. Soc. 1848, vol. iv. p. 239.

† For the most beautiful preparations of these infusorial earths, and especially for a selection of the most delicate organisms mounted separately, I am indebted to Mr. C. Poulton, of Southern Hill, Reading, whose skill in this department of

Infusorial earth from Lake Waihora.—I will close this account of the microscopic organisms by stating, that some white earth resembling magnesia in appearance, collected from the bed of the vast lake on the south-east of Banks' Peninsula, is made up of the usual lacustrine species and genera of *Diatomaceæ*; viz. *Gallionella, Bacillaria, Gomphonema, Micrasterias, Synhedra*; "*Meloseira,* resembling *M. varians, Cosmarium margaritaceum,* and *Rimularia viridis.*"—*Mr. Williamson.*

Mr. Henry Deane, of Clapham Common, informs me, that a few years since, a white earth was exported from New Zealand as native carbonate of magnesia; it was nothing more than the usual lacustrine organic deposits formed by the accumulation of innumerable minute frustules of *Diatomaceæ.*

Fossil Remains of Birds.

I now enter upon the examination of those remarkable relics which have invested the Palæontology of the Islands of New Zealand with the highest interest,—the remains of the Moa or Dinornis, Palapteryx, and other genera of birds of which no living species are known to naturalists. The collection of bones of the Class Aves, transmitted by my son in 1847, amounted to between 700 and 800 specimens: the present one comprises about 500, and 25 or 30 belonging to dogs and seals. The birds' bones are of various kinds of Dinornis and related genera, and of contemporaneous birds identical with, or closely resembling existing species of Albatros (*Diomedea chlororhynchus*), Penguin (*Aptenodytes*), Water Hen (*Brachypteryx*), Rail (*Notornis*), the nocturnal Parrot of New Zealand (*Nestor*), and the *Apteryx.*

In the catalogue accompanying the specimens the following are enumerated: viz. skulls and mandibles 8, tympanic bones 8, vertebræ 90, pelves 11, femora 17, tibiæ 17, fibulæ 10, tarso-metatarsals 23, phalangeals 90, ungueals 40; detached ribs, pubis, ischium, sacrum, and portions of sterna. A few bones of the anterior extremities or wings occur of Penguin, Albatros, and some unknown species; but not even a fragment that can be referred to the large Struthious forms.

About 200 bones are from the same locality in the North Island as those I had the honour of placing before the Society in 1848. The remainder are from the Middle Island, and chiefly from Waikouaiti, already mentioned.

On the former occasion the nature and position of the menaccanite sand-beds in which the bones from Te Rangatapu, in the North Island, were imbedded, were described as fully as the materials transmitted to me would allow. I have nothing to add to that description, as my son has not been able to revisit the spot and confirm or correct my previous statements; but in his last letter (dated Port Levi, Banks' Peninsula, September 1849), he mentions the discovery in the North Island of several extensive caverns lined with stalactites, about 175 miles inland from the Waingongoro bone-bed, and that bones of Dinornis and other animals had been found in their stalagmitic and

microscopic manipulation is well known. Mr. Rupert Jones also had the kindness to prepare many slides to assist my examination of the various earths sent by my son.

sandy floors. On his return from his present mission he intends to explore these caves and collect any relics they may contain. On the present series from Waingongoro I will therefore only remark, that it contains some very perfect tarso-metatarsals of that remarkable type, named *Aptornis* by Professor Owen*; a cranium and several upper mandibles of *Palapteryx*; crania of *Notornis*; and bones of genera and species undetermined. A circumstance is worthy of remark as indicative of the high antiquity of some of the bone deposits, namely, that Moa bones were obtained from a bed of sandy marl abounding in pipes of ironstone and masses of iron pyrites.

Moa Deposit at Waikouaiti.

The bones from the Middle Island are almost entirely from the locality in which Dr. Mackellar and Mr. Percy Earl collected the specimens described in Zool. Trans. vol. iii. p. 313–319. The ossiferous deposit at Waikouaiti is very dissimilar from that of Waingongoro. Instead of a fine dry incoherent volcanic sand, which has preserved the bones in a state of integrity, and but slightly altered in composition and colour, the bone-bed in the Middle Island is an ancient swamp or morass, in which the New Zealand flax (*Phormium tenax*) once grew luxuriantly; it is now covered by a layer of sand, and is submerged at high water, being visible only when the tide has receded. Its inland boundary is obscured by vegetation, but from the notes of my son, and the verbal account with which I have been favoured by Mr. Alfred Wills, who has recently arrived in this country from New Zealand, and who is well acquainted with the locality, the deposit appears to be of very limited extent.

Fig. 8.—*Sketch of the Coast at Island Point.*

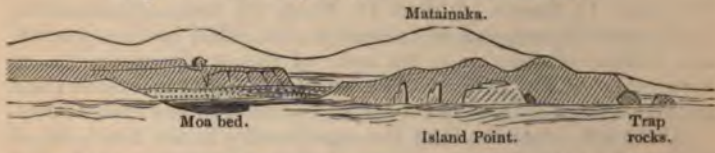
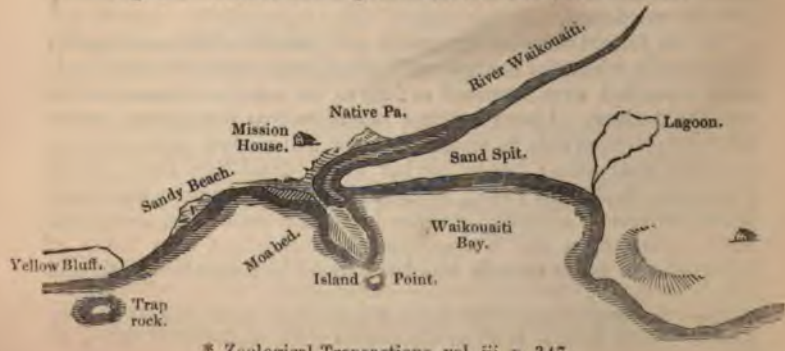


Fig. 9.—*Ground Plan of Waikouaiti and Island Point.*



* Zoological Transactions, vol. iii. p. 347.

The location of this bed is in a little bay, on the side of the bar of sand that unites the headland called Island Point with the mainland, at the entrance of the river Waikouaiti; this headland is about three-quarters of a mile in length, and 150 feet high.

The above sketch of the coast, and the annexed ground-plan will serve to illustrate the position of this remarkable accumulation of the extinct colossal bipeds of New Zealand.

This peat or rather flax-swamp, though soft and extremely fetid when fresh, dries into a dark brown friable inodorous mass*.

A microscopical examination shows that by far the largest portion consists of fibres of *Phormium tenax*; my son mentions that he sought diligently on the spot for vestiges of feathers and egg-shells, but unsuccessfully. The appearance and condition of the bones, as exemplified by the specimens, are similar to those presented by the mammalian remains exhumed from our peat bogs and morasses. Most of them have acquired a rich umber colour, and their texture is rendered tough and firm; even the periosteum is in many instances preserved†.

* My friend Dr. Gladstone, of University College, has obliged me with the following chemical examination of some of this deposit:—

"This substance is of a very heterogeneous character: it contains—

"1st. A brown marly earth, consisting mainly of alumina which gives off ammonia when heated, becoming at the same time black from the presence of carbonaceous matter.

"2nd. An earth considerably lighter in colour than the preceding, which contains lime. It is also impregnated with organic matter.

"3rd. Black decomposed woody matter.

"4th. Fragments of quartz.

"5th. Bones. There was a small vertebra of a grayish colour. Below it lay some small bones, or fragments entirely covered up by the earth. These are coloured of a reddish brown, and appear under the microscope to be enclosed in a sort of integument. Upon dissolving out the carbonate and phosphate of lime by means of acid, I found a soft mass remaining which blackened on exposure to heat. It was evidently the animal matter of the bone, and perhaps also some other portion of the animal which had dried upon it. Similar brown fragments were scattered throughout the mass of peat.

"Since flesh and feathers contain as much as 15 or 16 per cent. of nitrogen, I thought it possible that the peat-bog earth itself might indicate a considerable percentage of that element, if the soft parts of the birds were entombed along with their bones. A portion therefore was dried, the fragments of bone and quartz picked out, and the nitrogen was determined in the usual manner. It yielded however only 0·58 per cent. Now, as ordinary peat contains 2 per cent. or more of nitrogen, nothing favourable to such a view can be drawn from this experiment; but when we consider the large amount of earthy substances mixed up with the carbonaceous matter, it does not, I conceive, militate against the supposition."

† The shaft of one femur is in a remarkable state of preservation, the internal structure being as distinct as in a recent bone. Mr. Tomes, whose eminent skill in the microscopic investigations of osseous and dentinal organization is well known, obligingly made several sections of this specimen, and also favoured me with the following remarks:—

"The fragments of bone from the specimens of Dinornis remains, which you have recently received from New Zealand, show with unusual distinctness the characters of birds' bone.

"The microscope reveals that each Haversian canal is surrounded with from seven to twenty-five well-marked laminæ, which have slightly irregular or granu-

Although bones of various species of Moa, especially of the most gigantic kind, have been collected in considerable numbers and in great perfection from this locality, yet as the bed is rapidly diminishing from the encroachments of the sea, there is reason to fear that it will be entirely washed away, without yielding to the palæontologist all the desired information respecting the extinct animals whose relics it enshrines; for the Maoris or natives, and whalers, are well-aware of the interest attached to the bones by the Europeans, and they seize indiscriminately on any specimen that the receding tide may render visible; and if the bone cannot be readily extracted, what is exposed is broken off, and perhaps a most valuable relic destroyed, or mutilated and deprived of its most important characters. Their cupidity and avarice have too been so much excited by the large rewards given by casual visitors, that the cost of specimens has increased to an unreasonable amount. A residence near the spot, and diligent daily search, are required to ensure the acquisition of any connected portions of the skeleton of the same individual. An earnest of the treasures that might be obtained is afforded by the entire suite of bones composing the legs and feet of the same bird, which are now before us. "This pair of perfect feet," my son observes, "were discovered standing erect and about a yard apart, with the proximal epiphyses of the two tarso-metatarsals just visible above the soil.

Fig. 10.—*Position of the Moa's Feet in the Morass at Waikouaiti.*

"Upon the retiring of the tide, they were, fortunately, espied by 'Tommy Chaseland,' the best whaler in the island, who carefully dug them up. I examined the holes whence they were extracted,

lated edges, and that each layer has a thickness of from the 5000th to the 6000th of an inch; they may be seen equally well both in a longitudinal and transverse section of a large bone. In the latter section, the Haversian systems are very distinctly and strongly marked, and the outer laminæ may be readily distinguished from the inter-systemic layers of bone by the well-defined and uniform laminæ of the former, and the irregular laminæ of the latter, together with the irregular character of the inter-systemic lacunæ. The lacunæ of the Haversian systems lie sometimes in and sometimes between the laminæ, and have a length of about the 1000th, and a breadth of from about the 5000th to the 6000th of an inch; dimensions nearly similar to those stated by Mr. Bowerbank as characterizing bird-bone (Quarterly Journal of the Geological Society, vol. iv. page 9). Great numbers of canaliculi radiate from the lacunæ, but the majority of these proceed from the side nearest the Haversian canal and advance through the laminæ towards that part. The lacunæ of the inter-systemic layer of osseous substance give off relatively fewer and larger canaliculi, which proceed in equal numbers from each part of the circumference, in addition to which, the lacunæ are very irregular both in size and form. The canaliculi both of the systemic and inter-systemic lacunæ anastomose very freely, and through the medium of the latter the canaliculi of neighbouring Haversian systems are connected. I am not aware that these bones could by their structural characters be distinguished from those of other birds."

and have numbered every bone seriatim, to enable you to articulate them. This unlucky Moa, happily for science, must have been mired in the swamp, and, being unable to extricate himself, have perished on the spot. These splendid and unique fossils were presented to me by Mr. Jones. From the soil near them I dug out part of the lower jaw of a Sea-lion (*Phoca leonina*), which is enclosed."

No other locality in the Middle Island is specified by my son as containing birds' bones; but he incidentally mentions having seen fragments here and there in the subsoil of the plains. Mr. Alfred Wills, who has great local knowledge of New Zealand, and especially of the Middle Island, informs me that in the sand-spit near the mouth of the Molyneux river (now called the Cleuther), fifty miles south of Otago and north-east of the Kaihiku range, relics of Dinornis have been found; and also that fifteen miles inland from the mouth of the same river there is a hill about 100 feet high, called "*Moa Hill*," in consequence of bones having been observed in the superficial soil near its summit. The same intelligent traveller assures me that it is not uncommon to find small heaps of quartz pebbles wherever the bones are met with in any considerable number, and that these stones are supposed to have been swallowed by the birds. There is a native tradition that the Moa formerly inhabited the mountainous district of the Kaihiku range, which runs inland a few miles south of the Molyneux river.

I will now cursorily notice some of the most interesting osteological specimens in the collection; but I shall in a great measure avoid minute descriptions; for anatomical details, though of the highest importance in a physiological point of view, come more legitimately under the consideration of the zoologist than of the geologist; and I reserve for another Society the figures and descriptions of the new and most interesting specimens.

Dinornis, Palapteryx, &c.—The osteological characters of the extinct struthious birds of New Zealand have been so accurately and clearly determined by Professor Owen, in his memoirs on the Dinornis in the Zoological Transactions (vol. iii.), that I found no difficulty in assigning the principal bones in the collection to the several species of Dinornis, Palapteryx, and Aptornis, established by that eminent anatomist. The specimens from the Waingongoro deposit in the North Island, chiefly belong to the smaller species, namely *Dinornis didiformis, D. curtus, Aptornis otidiformis*, with *Dinornis casuarinus*, and a few of *D. giganteus*. The bones from Waikouaiti in the Middle Island are principally of the most gigantic birds, viz. *Dinornis giganteus, Palapteryx ingens*, associated with *D. struthioides, D. dromioides, D. casuarinus*, and *D. crassus*.

From both localities there are specimens which apparently belong to some undescribed species and genera of birds; and bones of a Dog, and of two species of Seal.

Some of the bones from Waikouaiti are of colossal size. The head of one tibia is 21 inches in circumference; femora, 16 inches long, and 8¼ inches in circumference at the middle of the shaft; vertebræ and portions of pelves of proportionate magnitude; a tarso-metatarsal

18 inches long. Several femora of the young of this gigantic species were collected; in these the epiphyses are wanting, and the walls of the shaft are in an immature state, the entire bone being very light and porous.

There are no portions of the skull sufficiently large for the *D. giganteus*; but there is one very large *os tympanicum* or *quadratum*—the bone articulating the lower jaw with the skull—which, according to the proportions of this element in the ostrich, indicates a cranium from 14 to 16 inches in length. From the activity of research my son has excited, there is reason to hope his efforts to obtain a perfect skull of the most colossal Moa will at no distant period be successful.

Feet of Dinornis robustus.—As the structure of the feet of the largest species of Dinornis is for the first time demonstrated by the pair of tarso-metatarsals, with the entire series of the bones of the corresponding toes in natural apposition, now before the Society, and which were dug up at Waikouaiti, as previously mentioned, the principal dimensions of the several parts are subjoined, that a record may remain for reference.

Tarso-metatarsal:—

	inches.	lines.
Length	17	0
Proximal end, circumference of	11	9
——, transverse diameter	4	6
——, antero-posterior	2	6
Circumference of the middle of the shaft	6	3
Antero-posterior diameter of ditto	1	8
Transverse diameter of shaft	2	6
—— of distal extremity	6	3
Circumference of ditto	15	6
Antero-posterior diameter of the middle trochlea	2	9

Phalangeal bones of—	*Outer toe.*		*Middle toe.*		*Inner toe.*	
	inches.	lines.	inches.	lines.	inches.	lines.
First or proximal phalangeal: length	3	2	4	3	4	9
Circumference of proximal end	5	9	6	9	6	6
Second phalangeal: length	1	9	2	6	1	9
Circumference of proximal end	4	9	5	3	3	0
Third phalangeal: length	1	0	1	9	ungueal 3	0
Circumference of proximal end	4	6	4	6	ungueal 4	0
Fourth phalangeal: length	0	11	ungueal 3	0		
Circumference of proximal end	4	0	ungueal 4	2		
Ungueal: length	2	6				
Circumference of proximal end	3	9				
Total length	9	4	11	6	9	6

The length of the toes when the bones are in close contiguity is about one inch less than the above measurements.

The transverse diameter of the expanse of the foot from the distal end of the outer toe to that of the inner one is 15½ inches. From the back of the trochlear extremity of the tarso-metatarsal to the extremity of the middle toe, 13 inches.

If to the actual measurements of the bones be added the proportional thickness of the cartilaginous coverings of the joints, and the callous integuments, the length of the foot of the living bird may be

estimated at 16 inches, and the width of its imprint at 17 or 18 inches.

According to the scale of proportions given by Professor Owen in the Zoological Transactions, the corresponding tibia of the tarso-metatarsal above described would be about 2 feet 9 inches, and the femur 14½ inches in length; the total height of the living bird about 10 feet. The larger tibiæ and metatarsals must have belonged to a bird yet more gigantic; and there is reason to conclude that some individuals attained a height of 11 or 12 feet, or one-third higher than the tallest Ostrich. I may add, that the height of some of the other species has been estimated by Professor Owen as follow:—

Palapteryx ingens, 9 feet.
Dinornis struthioides, 7 feet; the height of an Ostrich of moderate size.
—— *dromioides*, 5 feet, or that of the Emu.
—— *didiformis*, 4 feet, or intermediate between the Cassowary and the Dodo.

The largest Ornithichnite or fossil footmark in the sandstone of Connecticut, would be surpassed in size by the imprint of the foot of the most colossal Dinornis.

Phalangeal bones.—Among the numerous phalangeal bones belonging to birds of various species and ages, there are a few which do not present the characters of the Dinornis, but evidently belong to other genera. Among these are several which are relatively flatter and shorter, and somewhat resemble those of the Emu; and there are a few middle proximals in which the trochlear articulation is as unequally divided as in the Ostrich, suggesting the idea that didactyle or two-toed struthious birds may have inhabited New Zealand, contemporaneously with the colossal tridactyle Moa, and tetradactyle Apteryx and Palapteryx.

Egg-shells.—Of the egg-shell of the Moa, a few small portions, and one fragment 4 inches long and 2 wide, from Waingongoro, are the only additional examples. The sculpturings on the outer surface of the shells are of three distinct types, and unlike any recent eggs with which I have been able to compare them; they approach nearest to those of the Emu. Some burnt fragments of egg-shells, evidently charred when recent, were found in the ancient fire-heaps mentioned in my former paper, intermingled with roasted bones of dogs, Moas, and men. This fact tends to confirm the opinion that the Dinornis existed when cannibalism was practised by the aborigines of New Zealand.

The present collection has also established the interesting fact, that the *Apteryx australis*, the only known existing type of the Struthionidæ of these islands, was coeval with the more gigantic species of Dinornis and Palapteryx; the bones in my possession leave no doubt on that point. We have likewise evidence that the yellow-billed Albatros, and some species of Penguin, Water-rail, Teal, and Nestor, were comprised in that ancient ornithic fauna. The only terrestrial qua-

druped of which there are vestiges in the bone-deposits is a Dog; whether an extinct or living species is not determined.

Summary.—From the facts described, it appears that in the Middle Island of New Zealand, as in the North Island, the fundamental rocks are metamorphic schists and clay-slate, with dikes of greenstone and compact and amygdaloidal basalt, and intruded masses of obsidian, vesicular and trachytic lavas, and other igneous products. Hornblende and porphyritic rocks, gneiss and serpentine occur, but granite has not been observed.

The lofty mountain ranges of schistose metamorphic rocks that extend through the country, from near Cloudy Bay on the north-east to near the south-western extremity of the island, a distance of between 300 and 400 miles, and whose crests everywhere attain an elevation above the line of perpetual snow—hence they were called by Captain Cook "The Southern Alps"—are flanked by volcanic grits, and covered at their base by alluvial deposits, which have evidently originated from the decay of trachytes and earthy lavas, and the detritus of the harder materials which entered into their composition. No active volcanos are known in the Middle Island, nor have any extinct craters been discovered; but as the physical structure of the interior of the country, and especially of the Alpine districts, has been but partially explored, no conclusive inferences can be drawn from this negative evidence. Strata of limestone, composed of organisms similar to those which prevail in certain cretaceous beds of Europe, crop out in a few localities on the eastern coast, from near Morakura to Kakaunui; but their relation to the adjacent igneous and metamorphic rocks has not been ascertained.

A pleistocene or newer tertiary formation—the clay of Onekakara—abounding in shells of species existing in the neighbouring sea, overlies the limestone, and is in many places covered by the alluvial deposits of gravel, sand, conglomerate, and loam, which form the superficial soil of the vast plains that are spread over the eastern side of the central mountain chain.

On the western shore of the North Island, argillaceous strata with similar fossil shells appear at Wanganui, Waingongoro, &c.; in both islands these beds are from a few feet to 20 or 30 feet above the sea-level. A subsidence of the land to the depth of 40 feet would unite these outliers of a deposit, evidently once continuous; we may therefore conclude that an elevation to that extent has taken place since the deposition of the uppermost beds of the blue clay of Onekakara. This phenomenon accords with the horizontal sediments containing drift wood that occur along the coast, and with the terraces of boulders of trap, 50 feet high, and the lines of ancient sea-margins now far above the highest tides; and these mutations in the relative level of the sea and land must have taken place long since the Pacific was inhabited by the existing species of mollusca.

The infusorial earths show that deposits wholly composed of the

durable remains of the most minute structures have been in as rapid progress of formation at the Antipodes, as in Europe and America; and that among many familiar types there are, even in this "invisible world of being," unknown forms of animal and vegetable existence.

Lastly, the position of the Moa-bed at Waikouaiti has been correctly determined; like that of Waingongoro in the North Island, it is superimposed on the tertiary clay. Both these ossiferous deposits, though but of yesterday in geological history, are of immense antiquity in relation to the human inhabitants of the country. I believe that ages ere the advent of the Maoris, New Zealand was densely peopled by the stupendous bipeds whose fossil remains are the sole indications of their former existence.

The extreme freshness of the bones in no respect militates against this supposition, for many of the skeletons of the most ancient extinct mammalia in Europe and America have undergone as little change as the specimens before us. Thus Mr. Darwin remarks on the fossil mammalia of the Pampas: "As far as I am aware, not one of these animals perished, as was formerly supposed, in the marshes or muddy river-beds of the present land; their bones have simply been exposed by the streams intersecting the subaqueous deposit in which they were originally imbedded. The bones of the head (of the Toxodon) are so fresh, that they contain a large per-centage of animal matter, and when placed in a spirit-lamp burn with a bright flame*." And Sir Charles Lyell, in commenting on the discovery of the skeleton of the *Mastodon giganteus* dug up at Newburgh, observes, "Nothing is more remarkable than the large proportion of animal matter in the tusks, teeth, and bones of many of these extinct mammalia, amounting in some cases to 27 per cent.; so that when all the earthy ingredients are removed by acids, the form remains as perfect as in a recent bone subjected to the same process. It would be rash to infer from such data that these quadrupeds were mired at periods more modern than the fossil elephants found imbedded in similar clayey deposits in Europe†."

From the great numbers of the largest species of Dinornis that must formerly have existed, and the remarkable form and strength of their thighs, legs, and feet, constituting powerful locomotive limbs, well-adapted for traversing extensive plains, it seems probable that these stupendous terrestrial birds were not anciently confined within the narrow limits of modern New Zealand, but ranged over a vast continent, that is now submerged, and of which the Isles of the Pacific are the culminating points.

That the last of the species was exterminated by human agency, like the Dodo and Solitaire of the Mauritius, and the gigantic Elk of Ireland, there can be but little doubt; but ere Man began the work of destruction, it is not unphilosophical to assume that physical revolutions, inducing great changes in the relative distribution of the land and water in the South Pacific Ocean, may have so circumscribed

* Journal of a Naturalist, Edit. 1845, p. 155.

† Sir C. Lyell's Travels in the United States, vol. ii. p. 265.

the geographical limits of the Dinornis and Palapteryx, as to produce conditions that tended to diminish their numbers, preparatory to their final annihilation.

Of the law which determines the extinction of races of highly organized beings, and whose effects through countless ages Palæontology has in part revealed, we are as utterly ignorant as of that which governs the first appearance of the minutest living animalcule which the most powerful microscope enables us to descry:—both are veiled in inscrutable mystery,—the results only are within the scope of our finite comprehension.

I have thus endeavoured to present a general idea of the facts and inferences suggested by the collection of minerals and fossils, and the notes and sketches, communicated by my eldest son, in the hope that his attempts to illustrate the Palæontology of his adopted country, will be received by the Geological Society as an earnest of his anxious desire to advance, in however humble a degree, our knowledge of the ancient physical history of the earth and its inhabitants.

EXPLANATION OF THE PLATES.

PLATE XXVIII.

Fig. 1. Tooth of *Lamna*, nat. size.....
Figs. 2, 3. *Terebratula Gualteri*, n. sp., nat. size.....
Fig. 4. *Cereopora Ototara*, n. sp., magn.....
Fig. 5. *Cereopora Ototara*, magn. 2 diam. .....
Fig. 6. *Cereopora Ototara*, transverse section of the stem, nat. size
Fig. 7. *Cereopora Ototara*, transverse section of the stem, magn. ..
Fig. 8. Portion of *Eschara*, incrusting the upper part of fig. 4, magn.
Figs. 9–11. *Cereopora*, nat. size .....
Figs. 12, 13. *Manon*, nat. size .....
Fig. 14. *Manon*, magn. .....
} From the Ototara limestone.

Fig. 15. *Dentalium*, nat. size.....
Figs. 16, 17. *Turritella rosea*, nat. size .....
Figs. 18, 19. *Turbinoliæ*? nat. size .....
Fig. 20. *Pustulopora Zealandica*, n. sp., nat. size .....
Fig. 21. *Pustulopora Zealandica*, magn. 3 diam. .....
} From the blue clay of Onekakara.

PLATE XXIX.

[In this plate the objects are figured as seen by transmitted light, under magnifying powers of from 200 to 300 diameters.]

Fig. 1. *Textularia* .....
Fig 2. *T. elongata*, n. sp. .....
Fig. 3. *T. aciculata* .....
} From the Ototara limestone.

Figs. 4, 5. *Stauroneis Zealandica*, n. sp. .....
Fig. 5. *Stauroneis Zealandica*, the central bar, detached from the shield .....
Figs. 6, 7. *Surirella* .....
Fig. 8. *Pinnularia* .....
Fig. 9. *Actinocyclus* .....
Fig. 10. *Pyxidicula* .....
Fig. 11. *Polycystina* .....
} From the infusorial marl of New Plymouth.

Fig. 12. Spicule of *Gorgonia* .....From the Ototara limestone.

FOSSILS FROM NEW ZEALAND COLLECTED BY WALTER MANTELL, ESQ. 1848.

FOSSILS FROM NEW ZEALAND COLLECTED BY WALTER MANTELL.ESQ. 1848.

Note on Fossiliferous Deposits *in the* Middle Island *of* New Zealand. By Prof. E. Forbes, F.R.S.

Mr. Hugh Cuming, the eminent conchologist, has lately received from Mr. F. Manse a small collection of fossils from two localities in the Middle Island of New Zealand. Though in a very bad state of preservation, they are sufficiently perfect to enable us to determine the genera, and to pronounce whether or not they are identical with or different from known New Zealand fossils, or animals now existing in the neighbouring seas.

The one locality is at Banks' river. The fossils are imbedded in a greenish grey sandstone. They consist of shells of the genera *Solecurtus*, one species; *Tellina*, one species; *Lucina*, three species; *Cardita*, one species; *Artemis*, one species; *Pectunculus*, one species; *Crenella*? one large species; *Modiola*, coated with *Membranipora*; *Turritella*, one species very abundant; *Calyptræa*, one species; and *Trochus*, one species.

The other locality is at the cliffs of Blind Bay. The fossils are imbedded in a greenish conglomerate of small pebbles. They consist of a *Lucina*, a large species of *Arca*, a *Cardita* distinct from that at Banks' river; one species of each of the following genera, *Turbo*, *Fusus*? *Acmæa*, *Bulla*, *Tornatella*? and a *Haliotis*-like shell; also two fragmentary corals, apparently belonging to the genera *Turbinolia* and *Dendrophyllia*.

None of the fossils in either locality can be identified with any recent species. Their general aspect recalls very strongly that of eocene shells from the Bognor beds. The specimens have been presented by Mr. Cuming to the Museum of Practical Geology.

DONATIONS

TO THE

LIBRARY OF THE GEOLOGICAL SOCIETY,

January 1st to March 31st, 1850.

I. TRANSACTIONS AND JOURNALS.

Presented by the respective Societies and Editors.

Académie Royale des Sciences de Paris, Comptes Rendus de l'. Tome xxix. nos. 15–27. Deux. Série, and tome xxx. nos. 1–6.

Agricultural Society of England (Royal), Journal. Vol. x. part 2. no. 24.

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———— Journal of Science. Second Series, vol. ix. no. 25.

Athenæum Journal.

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Calcutta Journal of Natural History. Vol. i. *From Sir R. I. Murchison, V.P.G.S.*

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Dublin Geological Society, Journal. Vol. iv. part 2; and List 1849.

France, Société Géologique de, Mémoires. Deux. Série, tome iii. partie 2.—Bulletin. Deux. Série, tome vi. f. 34–43; tome vii. f. 1–3.

Geographical Society (Royal), Journal. Vol. xix. part 2.

Geological Society of London, Transactions. Vol. ii. First Series, and vol. ii. part 1. Second Series. *From the Royal Institution.*

Indian Archipelago, Journal. Vol. iii. nos. 10, 11, and 12.

Linnæan Society, Proceedings. Nos. 34–40.

———— List 1849, and Charter and Bye-Laws, 1848.

Milano, Imp. R. Instituto Lombardo di Scienze in, Memorie. Tomo i. and ii.

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——— Giornale. Tomo 1–8.

——— Memoria del Signor Francesco Meguscher i Boschi dell' alta Lombardia.

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——— Rapport lu dans la Séance du 5 Nov. 1849, Sur un Météore, par M. Leboucher.

——— Séance Publique, 1837.

——— Procès-Verbal des Séances de l'Institut des Provinces, tenues à Caen en Oct. 1846.

——— Note sur une tête de Crocodilien Fossile récemment découverte aux environs de Caen, par M. E. Deslongchamps.

——— Annuaire de l'Institut des Provinces et des Congrès Scientifiques, 1850.

——— Institut des Provinces de France. Exposition Régionale de Peinture, Sculpture, &c., pour le centre de la France, 1849.

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Scarborough Philosophical Society, 18th Annual Report.

Stockholm, Kongl. Vetenskaps-Akademiens Handlingar for 1847 and 1848.

——— Öfversigt af Kongl. 1848.

St. Pétersbourg, Académie Impériale des Sciences de, Mémoires. Tome vi. liv. 3, 5 & 6.

———— Bulletin de la Classe Physico-Mathématique, tome vii.

II. GEOLOGICAL AND MISCELLANEOUS BOOKS.

Names in italics presented by Authors.

Delesse, Achille. Various Memoirs extracted from the Bulletin of the Geological Society of France, &c.

Descloizeaux, A. Observations Physiques et Géologiques sur les principaux Geysirs d'Islande. *From Sir R. I. Murchison, V.P.G.S.*

Deville, Ch. Sainte-Claire. Recherches sur les principaux Phénomènes de Météorologie et de Physique Générale aux Antilles.

———. Voyage Géologique aux Antilles et aux Iles de Ténériffe et de Zogo. Études Géologiques, 3 liv.

D'Orbigny, Alcide. Prodrome de Paléontologie Stratigraphique Universelle des Animaux Mollusques et Rayonnés. Vol. i.

Gray, James. The Earth's Antiquity in Harmony with the Mosaic Record of Creation. *From Mrs. Buckland.* 2nd Copy, *from the Author.*

Helmersen, G. von. Herrn von Middendorff's Geognostische Beobachtungen auf seiner Reise durch Sibirien, B. I. Th. I. *From Sir R. I. Murchison, V.P.G.S.*

Lubbock, Sir J. W. On the Theory of the Moon and on the Perturbations of the Planets. Part 8.

Morton, S. G., M.D. Additional Observations on a new living species of Hippopotamus, of Western Africa.

Pareto, Marchese L. Osservazioni Geologiche dal Monte Amiata a Roma. *From Sir R. I. Murchison, V.P.G.S.*

———. Discorsi del, Presidente della Sezione di Geologia e Mineralogia all' ottavo Congresso Scientifico Italiano letti alle Adunanze dei Giorni 15 e 28 Sep. 1846. *From Sir R. I. Murchison, V.P.G.S.*

Pilla, L. Osservazioni Geognostiche da Napoli a Vienna. *From Sir R. I. Murchison, V.P.G.S.*

Reeve, Lovell. Conchologia Iconica. Monograph of the Genus Bulimus.

St. John, John R. A true description of the Lake Superior Country. *From the Rev. T. Hincks, LL.D., Hon. M.G.S.*

Taylor, Walton and Maberley. Two descriptive Catalogues of Works published by, 1850.

Thurmann, Jules. Essai de Phytostatique appliqué à la Chaîne du Jura, &c. Tome i. & ii.

Yandell, L. P., M.D., and B. F. Shumard, M.D. Contributions to the Geology of Kentucky. *From Dr. G. A. Mantell, F.G.S.*

THE

QUARTERLY JOURNAL

OF

THE GEOLOGICAL SOCIETY OF LONDON.

PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

MARCH 13, 1850.

Henry Hussey Vivian, Esq., and Henry Smith, Esq., C.E., were elected Fellows.

The following communications were read:—

1. *On the* METAMORPHIC *and* METALLIFEROUS ROCKS *of* EASTERN NOVA SCOTIA. By J. W. DAWSON, Esq.

[Communicated by the President.]

IN those parts of Nova Scotia lying eastward of the Shubenacadie River, and northward of Mines Basin and Channel, about half of the surface is occupied by carboniferous beds, whose arrangement has been noticed in various papers communicated to this Society*. The remainder, with the exception of a few small patches of new red sandstone and unaltered Silurian strata, consists of metamorphic rocks, for the most part older than the carboniferous system. These metamorphic rocks may, by evidence derived from mineral characters, geographical distribution, and associated fossiliferous beds, be divided

* Proceed. Geol. Soc. vol. iii. p. 711 (Mr. Logan); vol. iv. p. 124 (the President's Address); p. 184 (Sir C. Lyell); p. 186 with map (Dr. Gesner). Quart. Journ. Geol. Soc. vol. i. p. 26 with map (Mr. Dawson); p. 322 with map (Mr. Dawson); p. 393 (Sir C. Lyell); vol. ii. p. 133, organic remains (Mr. Dawson and Mr. C. Bunbury); vol. iv. p. 50 with map (Mr. Dawson); vol. v. p. 129 (Dr. Gesner).

into two great groups, which, so far as I am aware, have not hitherto been accurately distinguished by writers on the geology of Nova Scotia. In the present paper I propose to notice the composition, arrangement, and distinctive characters of these groups; and to describe, somewhat in detail, the metalliferous veins which have been discovered in one of them.

I. One of these metamorphic groups is, in the part of the province now under consideration, limited to the Atlantic coast and its vicinity. The prevailing stratified rocks in this group are, compact and flaggy grey quartzite (often weathering white), mica slate, and clay slate; the latter usually of dark colours, and occasionally passing into flinty slate and quartzite. These rocks usually occur in beds of great thickness. The hypogene rocks associated with them are white and flesh-coloured granite, which has penetrated the metamorphic rocks in large irregular bands and masses. The white granite, which is the most abundant, has white potash felspar, translucent slightly purplish quartz, and grey and black mica. I am not aware that any workable metallic deposits have been found in this group, or that any fossil remains are contained in it. As the association with granite is a somewhat characteristic feature, this group may, for the purposes of this paper, be named the *granitic* group of metamorphic rocks. It must not however be confounded with the granitic group of Dr. Gesner's arrangement*, which consists exclusively of hypogene rocks, and includes syenite, porphyry, and trap, belonging in my opinion to a different system.

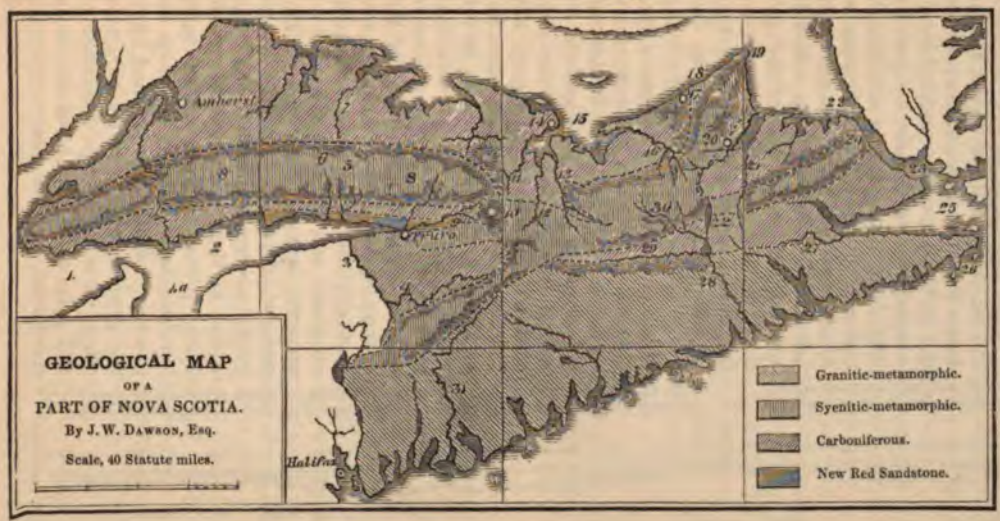
The granitic group forms a continuous, or nearly continuous belt along the Atlantic coast of the province, narrow at its north-eastern extremity, and apparently attaining its greatest development in the western counties. In the part of the province now under consideration, its southern or coast side has a general direction of S. 68° W.; its inland side, though presenting some broad undulations, has a general direction of about S. 80° W. Its extreme breadth at Cape Canseau, its north-eastern extremity, where it is bounded on one side by the ocean, and on the other by Chedabucto Bay, is only about eight miles. In its extension westward, it gradually increases in width, until at the head of the west branch of the St. Mary's River, eighty miles distant from Cape Canseau, it is about thirty miles in breadth. Westward of this point, it does not increase in breadth within the district to which this paper refers.

In the peninsula of Cape Canseau, mica slate is very abundant and presents many beautiful varieties†; it is associated with quartzite, clay slate, and granite. At the St. Mary's River, the northern side of the belt consists of a great thickness of grey quartzite, often flaggy and micaceous, and occasionally intersected by veins of white quartz. In the centre of the belt great masses of granite appear at a little distance from the river section, and nearer the coast, mica slate and

* Industrial Resources of Nova Scotia, p. 232.

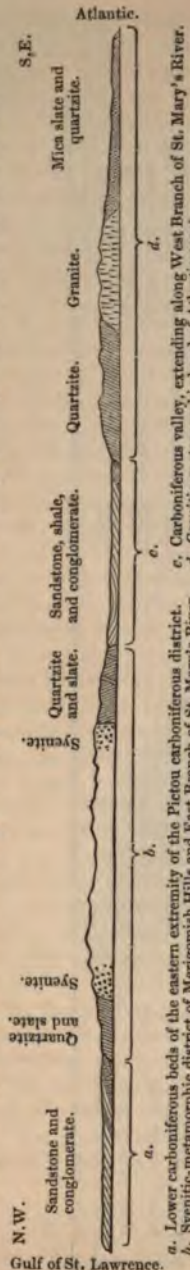
† I am indebted to Mr. Whiteman, of the Railroad Survey, for an interesting of specimens from this peninsula.

Fig. 1.



1. Mines Channel.
1 *a*. Mines Basin.
2. The Five Islands.
3. Shubenacadie River.
4. Stewiacke River.
5. Folly River.
6. Great Village River.
7. Wallace River.
8. 8. Cobequid Mountains.
9. Salmon River.
10. Mount Thom.
11. West River.
12. Middle River.
13. East River.
14. Pictou.
15. Merigomish Harbour.
16. Barney's River.
17. Arisaig.
18. Malignant Cove.
19. Cape St. George.
20. Antigonish.
21. South River.
22. Lochaber Lake.
23. 23. Gut of Canseau.
24. Cape Porcupine.
25. Chedabucto Bay.
26. Cape Canseau.
27. Salmon River.
28. St. Mary's River.
29. West Branch of St. Mary's River.
30. East Branch of St. Mary's River.
31. Musquodoboit River.

Fig. 2.—*Section from the Mouth of St. Mary's River to the Mouth of Barney's River.—Distance 50 miles.*



a. Lower carboniferous beds of the eastern extremity of the Pictou carboniferous district.
b. Syenitic-metamorphic district of Merigomish Hills and East Branch of St. Mary's River.
c. Carboniferous valley, extending along West Branch of St. Mary's River.
d. Granitic-metamorphic band of Atlantic coast.

quartzite prevail. Westward of the main stream of the St. Mary's River, clay slate and quartzite with masses of granite are the prevailing rocks.

The surface of this metamorphic belt is rugged and uneven, but not very elevated. The inland side is however somewhat higher than the parts nearer the coast, attaining in some places an elevation of about 600 feet; it abounds in small lakes and streams, and its coast line is much indented.

From the upper part of the west branch of the St. Mary's River to the head of Chedabucto Bay, the granitic group is bounded on the north by a valley occupied by sandstones, conglomerate, and shale, composed of the debris of the hypogene and metamorphic rocks; and containing a few *Calamites* and other fossil plants of the carboniferous system. This belt of carboniferous strata, which I explored and marked on the map of the province for the first time in 1845, separates in its whole length the granitic group from that next to be described. (See Section, fig. 2.)

II. In the second, as in the first metamorphic group, the prevailing rocks are slate and quartzite; these are, however, of much more varied characters. The former varies from greywacke to imperfect micaceous and talcose schists through many intermediate varieties of clay slate, and presents grey, olive, black and reddish colours. The latter is of every variety of texture, and ranges in colour from white to dark grey. These rocks are also more thinly bedded, and present more frequent alternations than those of the granitic group; at some points they are observed to pass into less altered rocks, containing organic remains; and in several localities they are traversed by metalliferous veins. The igneous rocks which have penetrated the strata of this group are very abundant, and exceedingly varied in their composition and characters. Their prevailing composition is felspathohornblendic, a character by which they are in general markedly distinguished from those of the granitic group. Syenite, greenstone of many varieties, compact felspar, claystone, and porphyries with bases of the two latter substances, are the most common of these

hypogene rocks. For our present purpose this group may be named the *syenitic* group of metamorphic rocks.

The most eastern point at which this group appears is Cape Porcupine in the Strait of Canseau, which presents a nucleus of reddish syenite, against which rest hard dark-coloured slates, apparently closely united to, and passing into, the syenitic mass. Cape Porcupine is separated from the eastern extremity of the granitic belt about twenty-four miles distant, by a tract of carboniferous rocks and the waters of Chedabucto Bay.

From Cape Porcupine, the southern margin of the syenitic group extends along the northern side of the carboniferous valley already referred to, for about sixty miles, with a course of S. 70° W. It then meets, and apparently unites with, the northern margin of the granitic group. At Cape Porcupine, the hypogene and metamorphic rocks occupy only three miles of the coast section, and attain an elevation of 500 feet. Westward of that point, they extend in a narrow, and perhaps in some places interrupted band, bounded on each side by carboniferous rocks for about forty miles, when they unite with a broader but very irregular promontory of similar rocks, extending toward Cape St. George. The triangular space intervening between these two metamorphic bands is occupied by carboniferous rocks.

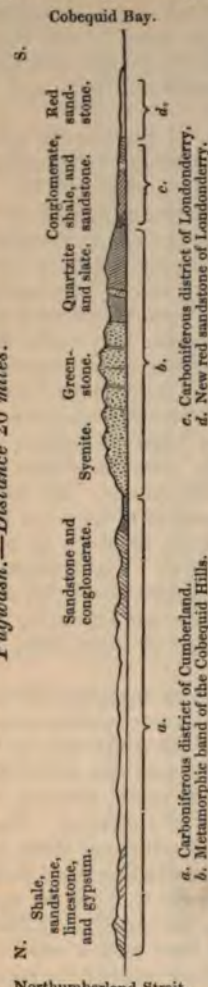
The metamorphic promontory extending to Cape St. George, and including the Antigonish and Merigomish hills, attains a greater elevation than the band connected with Cape Porcupine. At its extremity, however, it becomes divided into a number of detached hills and ridges, separated by lower carboniferous beds, to which in some cases the metamorphic action has extended itself. The Antigonish and Merigomish hills contain large masses of syenite, porphyry, compact felspar, and greenstone, associated with slates and quartzite. On their western side near Arisaig, there is a patch of shale, slate, and thin-bedded limestone, with Silurian fossils.

The northern boundary of the broad band of metamorphic and hypogene rocks, formed by the union of the two promontories already noticed, extends in a westerly direction along the south side of the Pictou carboniferous district, until it reaches the east side of the East River of Pictou, when it suddenly bends to the south, allowing the carboniferous strata to extend far up the valley of that river. Here, as at Arisaig, its margin includes a patch of fossiliferous slates and shales, among which is a thick bed of iron ore including fossil shells. A few of the fossils of these beds are stated by Sir C. Lyell to agree specifically with those of the Hamilton group of the United States geologists. Prof. Hall of Albany, to whom I have sent a small collection of these fossils, chiefly from Arisaig, where most of the species are the same with those of the East River, is of opinion that they belong to the age of the Hamilton and Chemung groups.

Immediately on the east of the East River, the metamorphic band is about fifteen miles in breadth, and includes masses and dykes of syenite and greenstone, and beds of quartzite and slate, the latter of very various colour and texture. Beyond the East River, the metamorphic band again widens; and between the upper part of the Middle River of Pictou and that of the west branch of the St. Mary's River (the

point to which we have already traced its southern boundary), it forms a broad and irregular tract of metamorphic country. Westward of this tract it is again subdivided; one branch extending near the margin of the granitic group, on the south side of the Stewiacke River, as far as the Shubenacadie River; another extending for a short distance between the Stewiacke and Salmon rivers; and a third, or rather a group of detached masses, extending through Mount Thom to the eastern extremity of the Cobequid range of hills. In the hilly country connected with Mount Thom, and in the vicinity of the upper parts of the Salmon, West, and Middle rivers, considerable breadths of lower carboniferous strata* have been partially metamorphosed, and invaded by greenstone and other igneous rocks. A mass of granite, containing dark grey felspar, abundance of black mica and very little quartz, occurs on the east side of Mount Thom.

Fig. 3.—*Section across the Cobequid Hills from the Mouth of Great Village River to Pugwash.—Distance 20 miles.*



The Cobequid hills, extending nearly in an east and west direction for about ninety miles in that part of Nova Scotia lying north of the southern arm of the Bay of Fundy, must be referred to the metamorphic group now under consideration. Both its stratified and hypogene rocks are similar to those of the parts of the syenitic group already described. Fossils are absent or very rare in those parts of it which I have explored. I have found only a few fish-scales, and fragments of a *Productus* or *Orthis* in calcareous bands associated with black slate and brown quartzite, near its eastern extremity. As the boundaries and general characters of the Cobequid range have long since been described by Dr. Gesner and others, and as I have in a former paper† noticed the structure of its eastern part, I shall at present confine myself to a description of the section of its central portion, afforded by the Great Village, Folly, and Wallace rivers, and the roads in their vicinity. (See Section, fig. 3.)

On the northern side of the hills, near the post road from Truro

* In the map attached to my paper on the Newer Coal Formation (Quart. Journ. Geol. Soc. 1845, vol. i. p. 322), some spaces in the south of Pictou and Colchester counties, occupied by hypogene and old metamorphic rocks, are coloured as carboniferous. These spaces, being then unexplored, were left uncoloured by me; but the colourist extended the carboniferous tint over them.

† Quart. Journ. Geol. Soc. vol. i. p. 27.

to Amherst, and also on Wallace River, the lowest rocks of the carboniferous system, consisting of reddish-brown conglomerates, are seen at the base of the hills. Their dip is to the northward at a high angle. On ascending the hills, masses of red, flesh-coloured, and grey syenite are seen, and rise rapidly to the height of several hundred feet; the northern side of the range being steeper and more lofty than the southern. The syenite of this part of the hills has often been described as a granite; but wherever I have observed it, it is a true syenite, containing reddish or white felspar, black hornblende, and nearly colourless quartz. Some of the red varieties are large-grained and very beautiful. The grey varieties are often fine-grained, and appear to pass into greenstone. On the summits of some of the highest ridges in this part of the range are numerous angular blocks of brownish sandstone, drifted from the lower carboniferous district lying to the northward.

Penetrating further into the range, we find thick dykes of greenstone, associated with slate and quartzite. The greenstone is of various degrees of coarseness, and at some points is penetrated by a network of syenitic or felspathic veins. The general course of the greenstone dykes coincides with that of the range of hills. Toward the southern side of the hills, grey quartzite, and grey, olive, and black slate prevail, almost to the exclusion of igneous rocks. The strike of these beds is nearly S.W. and N.E., with high dips to the southward. On the south they are bounded and overlaid unconformably by carboniferous conglomerate and sandstone.

The southern slope of the Cobequid hills is traversed by many deep transverse ravines, apparently due in great part to denudation. From the ridges dividing these ravines, as well as from the openings of some of them, extend long and sometimes very regular slopes of debris, made up of the fragments of the rocks of the hills; including the red syenite of their northern side, which was probably denuded in part by the same currents which deposited upon it the blocks of sandstone mentioned above.

The syenitic group of metamorphic rocks includes the most elevated land of eastern Nova Scotia. The Cobequid range, attaining at several points a height of 1000 feet, is probably the most elevated chain of hills in the province; and forms, in its whole length, the watershed dividing the streams flowing into Northumberland Strait and Chiegnecto Bay from those flowing into Cobequid Bay and Mines Basin and Channel. In like manner, the complicated group of hills extending westward from Cape Porcupine and Cape St. George, though less elevated than the Cobequid hills, contains the sources of all the principal rivers of the counties through which it extends. The largest of these is the St. Mary's River. Its western branch originating in the same elevated ground that gives rise to the Musquodoboit, the Stewiacke, and the Middle River of Pictou, flows for about thirty miles nearly due east along the valley which here separates the granitic and syenitic groups. Its east branch flowing from the hills in the rear of Merigomish, and passing near the lakes from which the principal branch of the East River of Pictou flows, receives

tributary streams from the metamorphic promontory stretching towards Cape Porcupine, and unites with the west branch at the northern margin of the granitic metamorphic band. The united stream then flows through a narrow valley in the granitic group to the Atlantic.

The groups of hills of the syenitic metamorphic system forming so important features in the physical geography of the eastern part of this province, were for the first time delineated with an approach to accuracy in a small geographical map compiled by the writer, and published in 1847. (See Map, fig. 1.)

Some of the facts already stated bear on the question of the relative ages of these metamorphic groups. That the metamorphism of the granitic group is of greater antiquity than the carboniferous period, is proved by the fact that the debris of its igneous and altered rocks is found in the lower carboniferous conglomerates; as, for example, in the valley of the west branch of the St. Mary's River, I have not found any evidence in that group of igneous action of a later date.

In like manner, at Cape Porcupine, Antigonish, Malignant Cove, the East River of Pictou, and along the whole base of the Cobequid hills, the lower carboniferous grits and conglomerates are filled with the debris of the rocks of the syenitic group, on which in many places they are seen to rest unconformably. The connection of this group with strata containing Upper Silurian fossils, renders it probable that a great part of its beds belong to the Silurian system. There is also evidence that igneous and metamorphic action were continued in this group during the carboniferous period. Instances of this have been mentioned above, and a very interesting example, occurring near Arisaig, has been noticed in a former paper*. This late continuance or renewal of igneous action is evidently connected with the very irregular distribution of those parts of the syenitic group in which it has occurred.

Assuming then that the group which I have named the *syenitic*, consists of altered Silurian and carboniferous strata, perhaps with some of Devonian age, though these have not yet been recognized, we may conclude that the beds of the *granitic* group belong either to some of the older members of the Silurian system, or to a still earlier period. In the part of Nova Scotia to which this paper is restricted, I have not been able to observe the actual superposition of the beds of these groups on each other; but in the western part of the province, where the syenitic and granitic groups are frequently found in contact with each other, it is possible that such evidence may be obtained.

Mineral Deposits of the Syenitic Metamorphic Group.

In a number of localities in this series, venigenous deposits of ores of iron and copper have been discovered. Some of these are of economical value; and are also interesting in the associations of minerals which they present, and in the inferences which may be deduced from

* Quart. Journ. Geol. Soc. vol. i. p. 330.

them in relation to the mode of their formation and the changes of the containing rocks.

The first of these deposits to which I shall refer is a vein of iron ore and ferruginous limestone, extending along the south slope of the Cobequid hills; and which has been most carefully explored in the vicinity of the Folly and Great Village rivers. This deposit appears to have been noticed as early as the time when the land on which it occurs was granted by the Crown; and it received some attention from Mr. Duncan and other gentlemen in Truro, nearly twenty years ago. No steps were however taken toward its scientific exploration until 1845. In the summer of that year I received a specimen of the ore for examination, and in October of the same year I visited and reported on the deposit. In the same autumn it was examined by Dr. Gesner. In 1846 I again visited it, and reported on it to C. D. Archibald, Esq., of London, and other gentlemen associated with him; and in the summer of 1849 I had the pleasure of again going over the ground and examining the vein at some new points, in company with J. L. Hayes, Esq., of Portsmouth, U. S. Since 1845, the extent and economical capabilities of the deposit have been discussed by several writers, both in this province and in Great Britain. In the following remarks I shall confine myself as far as possible to its geological relations, and facts bearing on its origin*.

I shall begin by describing the vein as it occurs on the west branch of the Great Village River, at the site chosen by C. D. Archibald, Esq., for the furnace and buildings of the "Acadia Mine." In the western bank of this stream, at the junction of the carboniferous and metamorphic series, a thick series of grey and brown sandstones and shales, dipping to the south at angles of 65° and 70°, meet black and olive slates, having a nearly vertical position, and with a strike N. 55° E. The dip of these slates, where apparent, is to the southward, and the strike of the slaty cleavage and of the bedding appear to coincide. Near the Falls of the river, a short distance northward of the junction just noticed, the slates give place to grey quartzite, which, with some beds of olive slate, occupies the river-section to, and for some distance beyond, the iron vein.

The vein is well seen in the bed of the stream, and also in excavations in the western bank, which rises abruptly to the height of 327 feet above the river bed. In the bottom of the stream it presents the appearance of a complicated network of fissures, penetrating the quartzite and slate, and filled with a crystalline compound of the carbonates of lime, iron, and magnesia, which, for reasons to be stated in the sequel, I refer to the species *Ankerite*. With this mineral there is a smaller quantity of red ochrey iron ore, and of micaceous specular iron ore.

In ascending the western bank of the stream, the vein appears to increase in width and in the quantity of the ores of iron. In one place, where a trench was cut across it, its breadth was 120 feet.

* The localities referred to in the following paragraphs will be found in the map of the New Red Sandstone district of Nova Scotia, 1847, Quart. Journ. Geol. Soc. vol. iv. p. 50, pl. 5.

Though its walls are very irregular, it has a distinct underlie to the south, apparently coinciding with the dip of the containing rocks. As might have been anticipated from its appearance in the river-bed, it presents the aspect of a wide and very irregular vein, including large angular fragments of quartzite, and of an olivaceous slate with glistening surfaces. These fragments are especially large and abundant in the central part of the vein, where they form a large irregular and interrupted rocky partition.

The ankerite should evidently be considered the veinstone, as it surrounds and includes all the other contents of the vein, and greatly exceeds them in quantity. Where not exposed, it is white and coarsely crystalline. On exposure it becomes yellowish; and near the surface, as well as on the sides of fissures, it is decomposed, leaving a residue of yellow ochrey hydrous peroxide of iron. In some parts of the vein, the ankerite is intimately mixed with crystals and veinlets of yellowish spathose iron. The red ochrey iron ore occurs in minor veins and irregular masses dispersed in the ankerite. Some of these veins are two yards in thickness; and the shapeless masses are often of much larger dimensions. Specular iron ore also occurs in small irregular veins, and in disseminated crystals and nests. At one part of the bank there appears to be a considerable mass of magnetic iron ore, mixed with specular ore; this mass was not, however, uncovered till after I had left the ground.

The whole aspect of the vein as it appears in the excavations in the river bank is extremely irregular and complicated. This arises not only from the broken character of the walls, the included rocky fragments, and the confused intermixture of the materials of the vein; but also from the occurrence of numerous transverse fissures, which appear to have slightly shifted the vein, and whose surfaces usually display the appearance named "slickenside," and are often coated with comminuted slate or iron ore. In some places these are so numerous as to give an appearance of transverse stratification. One of them was observed to be filled with flesh-coloured sulphate of barytes, forming a little subordinate vein about an inch in thickness.

The general course of the vein, deduced from observations made by Mr. Hayes and myself at the Acadia Mine and further to the eastward, is S. 98° W. magnetic, the variation being 21° west. At the Acadia Mine this course deviates about 33° from that of the containing rocks. In other localities, however, the deviation is much smaller; and in general there is an approach to parallelism between the course of the vein and that of the rock formation of the hills, as well as that of the junction of the carboniferous and metamorphic systems. The vein for a space of seven miles along the hills is always found at distances of from 300 yards to one-third of a mile northward of the last carboniferous beds, and always in the same band of slate and quartzite.

Westward of the Acadia Mine, the course of the vein over the high ground is marked by the colour of the soil, as far as Cook's Brook, about a mile distant. The outcrop of the ore is not exposed in this brook, but large fragments of specular ore have been found in its bed,

and a shaft, sunk on the course of the vein, has penetrated more than forty feet through yellow ochre containing a few rounded masses and irregular layers of ankerite. At this point the decomposition of the ankerite and spathic iron has extended to a much greater depth than usual, and is so perfect that a specimen of the yellow ochre was found to contain only ·4 per cent. of the carbonates of lime and magnesia; the remainder being hydrous peroxide of iron, alumina, and siliceous matter.

Still further west, in Martin Brook, I have observed indications of the continuation of the vein. Beyond this place I have not traced it; but I have received specimens of specular iron ore and ankerite from the continuation of the same metamorphic district, as far west as the Five Islands, twenty miles distant from Acadia Mine.

On the east side of the west branch of the Great Village River, the ground does not rise so rapidly as on the western bank, and the vein is not so well exposed. On this side, however, a small quantity of copper pyrites has been found in or near the vein, but it does not seem to be of any importance. Indications of the vein can be seen on the surface as far as the east branch of the river. In the east branch, red and grey conglomerates, dipping to the south, and forming the base of the carboniferous system, are seen to rest unconformably on olive, black and brown slates, whose strike is S. 75° W. The continuation of the iron vein has not yet been observed in the bed of this stream.

Further eastward, on the high ground between the Great Village and Folly rivers, indications of the ores of iron have been observed; especially near the latter river, where in two places small excavations have exposed specular and red ores, and where numerous fragments of brown hæmatite are found scattered on the surface. On the elevated ground a short distance westward of the Folly River, on Mr. Fleming's farm, the lower carboniferous conglomerate rises higher on the slope of the hills than at any other place in this vicinity, and approaches within 300 yards of the iron vein. In the banks of a small brook near this place, the conglomerate is well seen, and a good section of the underlying slate and quartzite is exposed; but we could find no other indications of the continuation of the vein, than slender strings of ankerite, with disseminated crystals of specular iron ore.

The ravine of the Folly River affords a good natural section of the quartzite and slate of the hills, as well as of the carboniferous beds of the lower ground. A sketch of this section, as far as the base of the hills, is given in my paper on the New Red Sandstone of Nova Scotia*. The lowest carboniferous bed is a thick, coarse, grey and brownish conglomerate, dipping S. 20° W. It rests unconformably on a bed of slate very similar to that seen in a similar position at the Great Village River, and which differs considerably in appearance from most of the slates of these hills. The strike of the slate is S. 70° W.; and that of the bedding and slaty structure appear to correspond. In a layer of greywacke included in this slate, I observed small and well-

* Quart. Journ. Geol. Soc. vol. iv. pl. 5. sect. 1.

rounded pebbles of light-coloured quartz. This slate is succeeded by thick beds of grey quartzite and hard olivaceous slates. These occupy the river-section for about 700 yards, or as far as the "Falls," where the river is thrown over a ridge of quartzite fifty-five feet in height; a small rill pouring in on the eastern side from a much greater elevation. Between the conglomerate and the waterfall, the quartzite contains a few narrow strings of ankerite, and at the fall there is a group of reticulating veins, some of them six inches in thickness. They contain a little iron pyrites. These are the only indications of the iron vein observed in this section; and as the group of beds in which it should occur is well exposed, it is probable that it is represented here only by these small veinlets distributed over a great breadth of rock. Above the fall the quartzite and slate continue to alternate for a considerable distance; the dip being generally to the southward, in one place at as low an angle as 55°. About a quarter of a mile above the fall, they are traversed by a dyke or mass of fine-grained hornblendic igneous rock.

On the elevated ground, east of the Folly River, the vein is again largely developed, and two excavations expose a part of its thickness on the property of the Londonderry Mining Company. The excavation nearest to the river shows a thickness of 190 feet of rock on the south side of the vein. This consists of grey quartzite, olive slate, and about three feet of black slate. These beds are traversed by a few small strings of ankerite, which increase in dimensions on approaching the broken and irregular wall of the vein. About seventeen feet of the south side of the vein consists principally of ankerite. Adjoining this on the north is red iron ore with nests of specular ore, veins and blocks of ankerite decomposed in part to yellow ochre, and fragments of rock. Ten feet in thickness of this red ore is seen without exposing the north wall of the vein.

On the surface in this vicinity are large fragments of brown hæmatite, which mark the course of the vein. In the eastern excavation, this mineral is seen in place near the surface and occupying fissures in a fragment of quartzite. In this second excavation the red ore is more largely mixed with the micaceous specular variety, and also includes large rounded blocks of ankerite and angular fragments of rock. The width exposed here is thirteen feet, and neither wall is seen. The ankerite is decomposed to the depth of eight feet. The same appearance of transverse vertical layers seen at the Acadia Mine is observed here, and is probably due to the same cause.

Still further east, on the property of C. D. Archibald, Esq., and on ground equally elevated, three excavations have shown a still greater development of the vein. A trench fifty-three feet in length, and nearly at right angles to the course of the vein, shows in its whole length a mixture of red and specular ores with ankerite. Another excavation ninety-five feet to the northward of the first, exhibits ankerite tinged of a deep red colour by peroxide of iron, and traversed by reticulating veins of red iron ore. A third opening, 365 feet southeastward of the first, shows white and grey ankerite, having some of its fissures coated with tabular crystals of white sulphate of barytes.

The walls of the vein are not seen at this place; but 150 paces south of the first trench, a thick dyke of greenish igneous rock, apparently a very fine grained greenstone, appears, with a course of S. 102° W. This dyke is not seen westward of this place, but it can be traced for a considerable distance to the eastward. In the Mill Brook, two miles east of Folly River, it appears in connection with a bed of black slate near the margin of the metamorphic system, and probably a continuation of that seen in a similar position in the Folly and Great Village rivers. At the Mill Brook, the dyke is about 100 feet in thickness.

In the bed of the Mill Brook, the vein is seen in the form of a network of fissures chiefly filled with ankerite; and in its eastern bank it attains a great thickness. In the bank of another brook still further to the eastward and in the same line of bearing, it appears to be of large dimensions, and contains abundance of red iron ore and red ankerite. I have not traced it further to the east, but I have no doubt of its continuance to a great distance in that direction.

I shall now present a few facts and inferences bearing on the manner in which this deposit may have been produced.

The ferruginous magnesian limestone which I have named *ankerite*, differs somewhat in composition from the European specimens on which that species was founded. The mean of two analyses which I have made of specimens from the Folly River is,—

Carbonate of lime	54·6
Carbonate of iron	23·2
Carbonate of magnesia	19·5
Silica	2·7
	100·0

Specimens from other parts of the vein, which I have examined qualitatively, contain the same substances; the red ankerite having in addition a variable proportion of the peroxide of iron. The specific gravity of a specimen from the Folly River is 2·916, that of a specimen from the Acadia Mine is 2·997. The other external characters of these specimens correspond with those of ankerite. Perfect uniformity of composition in compounds of this kind from different localities can scarcely be expected, and indeed where the constituents are so nearly isomorphous, species founded on chemical characters must graduate into each other. For this reason, although my specimens are destitute of the small percentage of manganese found in European specimens of ankerite, and differ somewhat from these latter in the proportions of their other ingredients, I have thought it advisable to refer them to that species. Even if the absence of manganese, or any external differences which may be found on a comparison with European specimens, should hereafter be considered sufficient to establish a specific distinction, my application of the name ankerite can, with the above explanation, lead to no misconception.

The absence of cavities and 'combs' in the ankerite, its pretty uniform coarse granular structure, its perfect penetration of all the

fissures of the containing rock, and its included rocky fragments, render it probable that it is a true injection-vein or dyke. I could not observe that any unusual degree of metamorphism of the containing rock occurred in the vicinity of the ankerite. The walls of the vein, however, and its included fragments often consist of a peculiar olive slate with shining surfaces, and approaching in appearance to a steatite schist. This slate contains silicate of magnesia, though not in large proportion; and possibly its composition and appearance may be due to the eruption of a highly magnesian rock such as the ankerite. As I did not, however, give very particular attention to this circumstance when on the ground, I am not prepared to affirm that this magnesian slate is confined to the vicinity of the vein.

True *spathose iron* is of rare occurrence in the outcrop of the vein. At the Acadia Mine, where it occurs in intimate mixture with the ankerite, it contains about twenty per cent. of carbonate of magnesia, approaching in this respect to the species Mesitine spar, though its proportion of magnesia is much smaller. It also contains about six per cent. of carbonate of lime. This spathose iron is evidently of contemporaneous origin with the ankerite.

The *yellow ochre* which abounds in the superficial parts of the deposit, and which at Cook's Brook extends to a considerable depth, is evidently a product of the decomposition of the ankerite and spathose iron, under the influence of air and moisture. The latter substance being the more easily decomposed of the two, and being found in some places mixed with the ankerite, it is possible that a larger proportion of the yellow ochre has resulted from its decomposition, than would be inferred from the relative proportions of ankerite and spathose iron at the surface. No evidence appears that any considerable portion of the yellow ochre can have resulted from the decomposition of metallic sulphurets.

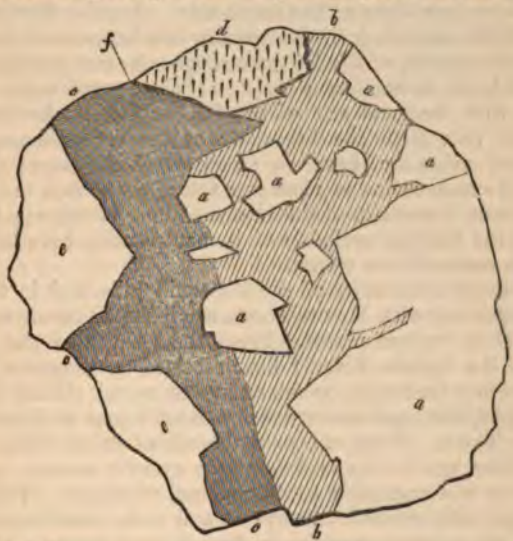
The veinlets, nests, and disseminated crystals of *specular* and *magnetic iron ore*, which are scattered through the vein, are probably results of segregation and sublimation; and were probably introduced at the same time with the ankerite.

The *red ochrey iron ore*, which abounds in most parts of the vein, is, in reference to its origin, one of the most difficult features of the deposit. In some parts of the vein it is a very pure peroxide of iron. A specimen analysed by me gave 98 per cent. of that substance. By gradual additions of the carbonates of iron, lime, and magnesia, it passes into spathose iron or red ankerite. Its earthy and porous texture, its traces of crystalline form, and its connection with the minerals just named, point to the only theory of its origin which I have been able to form—that of metamorphism of carbonate of iron by heat. This substance is in appearance a roasted carbonate of iron; it may be seen to pass by insensible degrees into that mineral, and it often retains traces of its external form and cleavage.

If we suppose that the vein originally contained a considerable quantity of the carbonate of iron, and that after it was filled and its contents consolidated, heat accompanied by access of oxygen was applied, we have the conditions required for the production of

the ochrey red ore. The irregularity of its distribution would result from that of the carbonate of iron, which, where it now occurs in the vein, is seen to be confusedly mixed with the ankerite. It might also happen that the heat would act most powerfully along lines of fissure, and of this there are some evidences in the appearance of the vein. The comparatively unaltered state of the ankerite is explained by the fact, that it is less easily decomposed by heat than the pure carbonate of iron, or even than the spathose iron found at Acadia Mine. If a small fragment of the mixed white ankerite and spathose iron from Acadia Mine be exposed to a low red heat with access of air, the carbonate of iron is completely decomposed, before any other change than a slight discoloration is produced in the ankerite. Hand specimens from the Acadia Mine often present appearances highly illustrative of the relations of the red ore to the other ingredients of the vein, and confirmatory of the above views of its origin. Fig. 4 is a sketch of one surface of a specimen of this kind.

Fig. 4.—*Surface of a Hand-Specimen from Acadia Mine.*



a. Ankerite.
b. Spathose iron.
c. Red iron ore.
d. Fragment of slate.
e. Ankerite with surface changed into yellow ochre.
f. Fissure lined with red ore.

The *brown hæmatite* is apparently confined to the superficial parts of the vein; and indeed appears to have been more abundant in those parts of it which have been removed by denudation, than in any now remaining. It is no doubt a product of the action of water on the carbonate and hydrated oxide of iron, near the outcrop of the vein.

The *sulphate of barytes*, occurring in small quantities in some parts of the vein, must also be a product of aqueous infiltration.

The facts which I have obtained in relation to the age of this de-

posit are few and not very decisive. The character of the fissure in which the vein is contained, leaves little doubt that the metamorphism of the containing rocks was complete or nearly so before its formation. If, as seems most probable, these rocks be of Silurian age, and if, as the lower carboniferous conglomerates testify, their metamorphism occurred before the commencement of the carboniferous deposits, we have a limitation of the age of the vein, at least in one direction. On the principles stated in my paper on the Colouring Matter of Red Sandstones*, the metamorphosed carbonate of iron of this deposit might have produced on aqueous deposits, formed contemporaneously with or subsequent to its metamorphism, effects in relation to colour similar to those which I have supposed to result from the decomposition of sulphuret of iron. The carboniferous beds at the base of the hills, however, do not present any greater amount of the peroxide of iron than the same beds in other localities; and are indeed, in comparison with those of the opposite side of the Bay of Fundy, rather deficient in this respect. The carboniferous beds of the northern side of the hills are indeed more highly coloured by red oxide of iron than those of the south side. Another fact bearing on the age of this deposit, is the occurrence, in other parts of the syenitic metamorphic group, of slender veins of specular iron ore and ankerite in altered lower carboniferous rocks. If these small veins be of the same age with the great vein of the Cobequid hills, the latter must be of later date than the beginning of the carboniferous period. These small veins are, however, at too great a distance from that now under consideration to allow any actual connection to be traced. On the whole, it seems probable that the filling of this vein is of later date than the Silurian period, and it may possibly have been posterior to the carboniferous epoch.

In the eastern extremity of the Cobequid hills, and in the group of hills connected with Mount Thom, small metalliferous veins have been found in various places. From the vicinity of the northern branch of the Salmon River I have received specimens of specular iron and brown hæmatite, contained in quartz-rock similar to that of the Cobequid hills, and similar specimens are found in different parts of Mount Thom. From the south branch of Salmon River I have received, from small veins in slate of the syenitic system, specimens of copper pyrites containing 31·6 per cent. of copper. This pyrites is associated with sulphate of barytes; and in the same locality there are veins of ankerite, containing disseminated crystals of copper pyrites. Near the salt springs at the West River of Pictou, veinlets of specular iron occur in altered lower carboniferous beds. In brooks, emptying into the West River and the upper part of the Middle River, both specular iron and ankerite occur in slender strings. Such appearances are indeed very common in all that tract of metamorphic country lying to the south of the Pictou carboniferous district. In the vicinity of the East River of Pictou, however, there are other deposits of iron ore which must not be confounded with these veins of the metamorphic rocks. One of these is the conformable bed of per-

* 1848. Quart. Journ. Geol. Soc. vol. v. p. 25.

oxide of iron and quartzose sand occurring in the Silurian system, and containing marine shells already mentioned. Others are veins of brown hæmatite, apparently confined to the lower carboniferous beds, near their junction with the Silurian system.

In the promontories of metamorphic and igneous rocks, extending toward Cape St. George and Cape Porcupine, veins similar to those already described occur in many places. In the former, at Malignant Cove and other places in that vicinity, specular iron ore occurs in slender veins, whose walls are sometimes lined with crystals of epidote. In the latter, near the Lochaber Lake, a mineral district of somewhat interesting character has been discovered. At this place the prevailing rocks are olive, black, and grey slates, and grey quartzite, with dykes of greenstone and claystone. The general strikes of the beds are S. 70° W. to S. 20° W. magnetic; and the directions of the bedding and slaty structure correspond. The slates are often very fine-grained and soft, with glistening surfaces, and highly perfect slaty structure. In the slate and quartzite there are innumerable small veins of white quartz and ankerite, with micaceous specular iron and occasionally iron and copper pyrites. The general direction of these veins corresponds with that of the containing beds, though they are often seen to pass from one plane of bedding or cleavage to another. On the south side of Polson's Lake, two miles eastward of the Lochaber Lake, a large vein of iron and copper ore appears to exist. The slate is here decomposed to a great depth, and among its debris are numerous large fragments of ore marking the outcrop of the vein. Some of these fragments are from three to five feet in diameter. They consist of red ochrey iron ore, with many and often large strings and bunches of copper- and iron-pyrites. No specular iron ore has yet been found in this vein, but there are small quantities of greyish crystalline carbonate of iron, which may be observed to pass gradually into the red ochrey ore, the latter retaining, often in great perfection, the rhombohedral crystallization of the carbonate of iron. In this we have probably evidence of a change similar to that already supposed to have produced the red ore of the Cobequid hills. Where the carbonate of iron is exposed to the weather, it is occasionally seen to be changed into yellow and brown hydrous peroxide of iron.

The pyrites found in this deposit contains from 4 to 17 per cent. of copper. The most common variety has 10·8 per cent. It is scattered through the red ore in the most irregular manner; but in general the boundary between the two minerals is marked by a thin crust of hydrous peroxide of iron, perhaps resulting from the decomposition of the surface of the pyrites by water percolating the porous red ore. The larger masses of pyrites occasionally include fragments or crystals of ankerite and carbonate of iron. I confess that the occurrence of minerals so easily altered by heat, as copper and iron pyrites, in association with red ore, is adverse to the view of the origin of that mineral given above; unless we can suppose the pyrites to have been introduced subsequently to the production of the red ore.

I first heard of these deposits in 1845, when exploring the country in the vicinity of the St. Mary's River, but at that time I had not leisure to visit them. I examined them with more care in the spring and summer of 1848; and I believe there is a prospect that mining operations will soon be commenced on the vein near Polson's Lake, which promises to be a valuable deposit of copper pyrites, and is I believe the first workable copper vein discovered in the metamorphic districts of Nova Scotia.

At South River Lake, two miles eastward of Polson's Lake, specular iron ore is said to occur in large quantity. The metamorphic country eastward of this place, and that lying immediately westward of the Lochaber Lake, have been little explored. In the east branch of the St. Mary's River, about seven miles westward of Lochaber Lake, though the rock formations are similar to those eastward of that lake, I saw no metalliferous veins.

The mineral deposits of the metamorphic districts, to which this paper refers, have only recently attracted public attention; and it may be anticipated that every year will extend our knowledge of these deposits. The details of the rock formations themselves still remain to be worked out; and in the present state of these districts this must require much time and labour. It is also evident that the transition from highly metamorphic to unaltered Silurian and carboniferous beds, on the confines of one of these metamorphic groups, must oppose great difficulties to the accurate mapping-out of the limits of those systems in this part of Nova Scotia. In the mean time, the facts contained in this paper may aid in the formation of general views of the geology of this province; and may afford some new terms of comparison with the metamorphic rocks and mineral veins of other countries.

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2. *On the* Structure *of the* Crystalline Rocks *of the* Andes, *and their* Cleavage-Planes. By Evan Hopkins, F.G.S.

It is a well-known fact to those who have traversed large areas of uncovered crystalline rocks, that they present a structure more or less vertical. In North America, Scotland, and Sweden the diversified edges of the crystalline series may be traced for many miles, presenting a north-easterly structural bearing. Where argillaceous sedimentary beds have been deposited on crystalline rocks, having the above vertical structure strongly developed, I have frequently observed the latter, by a slow chemical action, in the course of time obliterate the seams of deposition in the former, and cleave the beds in conformity to the angular position of the primary structure and the disposition of the crystals in the crystalline base.

These cleavage-planes pass through mountains of undulated beds, and preserve throughout the various contorted seams, the geometrical parallelism of the structure of the parent rock below; thus plainly showing the effect of a polar crystallizing force, acting gradually and insensibly on the whole mass in one direction to an indefinite extent.

Many thousand square miles of this vertical structure may be seen in South America, and in magnificent sections several thousand feet deep, exhibiting a great variety of colours, crystallization, and transitions of the primary series;—as may be observed on reference to the sections exhibited to the Society, which have been carefully made from a very laborious survey carried on during many years, geologically, mineralogically, barometrically, and trigonometrically. This survey was not alone confined to the surface, but it comprehends the results of very extensive subterranean explorations in various parts of the Andes.

One section, not published with this paper, intersects the three branches of the Cordilleras in latitude 5° 10′ N.; from the Paramo of Chingasá to the head of the river Atrato, and passes through the silver-mines of Mariquita and the gold-mines of Supia, and many other mining localities of great interest.

The accompanying section (Plate XXXI.) crosses the central Andes in latitude 4° 20′ N., from the plains of the river Meta (a tributary of the Orinoco) to the shores of the Pacific Ocean at Choco; being about 260 geographical miles from E. to W. It exhibits at one glance a great variety of rocks, crystalline and sedimentary, including also the gold regions.

Another section has been made which passes through the emerald mines of Muzo, the various marbles and granites near Nace, and other important rocks, on the banks of the Rio Negro in Antioquia, in latitude 7° N. The accompanying section, however, will, I trust, serve the purpose of this paper. It would occupy too much time to enter into the details of all the rocks, their uniform vertical structure, and their respective transitions; therefore I shall simply state in general terms that the great Cordilleras are formed of innumerable varieties of granites, gneiss, schists, hornblende, chloritic slates, porphyries, &c., as noted in the section, and these rocks alternate with each other in great meridional bands; which in the ridges frequently present the appearance of a radiated or fan-shaped structure, and under the plains are more or less vertical. The bearing of the cleavage-planes of the structure is quite independent of the direction of the ridges, secondary chains, or the sinuosity of the valleys:—they pass for hundreds, indeed I may say thousands, of miles in a geometrical order, through all the superficial undulations without deviation, on an average bearing of about 30° N.E. This uniformity of bearing causes the prevalence of this strike in the older sedimentary rocks, which have been altered, and cleaved in the direction of the primary structure, as seen in Wales, and in the roofing-slate districts of the Continent.

On reference to the section it will be seen that the crystalline rocks follow no particular order in the alternation, as commonly supposed; on the contrary, we find only granites and gneiss for miles; and again schist, quartz, gneiss, &c. interchanging.

However, there is one general order in the compound both vertically and longitudinally, viz. *each variety of schist depends on its crystalline parent below*, that is, on the quality of the granitic base.

The whole of the crystalline rocks, especially the micaceous variety, pass insensibly from the crystalline to the laminated structure. For instance, we have first the granitic base in which the crystals are somewhat confusedly mixed; these gradually become arranged upwards into parallel lines, and the rock is then called gneiss; by degrees the felspar is decomposed and the mass becomes schistose, with inclosed veins of the predominating element of the compound below, as exhibited in various parts of the section. Such is the general character of the primary structure of the Andes.

There are many beds of sandstones, limestones, &c. covering the above, especially on the eastern chain. The sedimentary formation of Bogotá containing coal is very extensive, and is at a very high elevation, 8872 feet above the level of the sea. Some of the fossils were presented to the Society in 1843, and described by Professor Forbes in 1844*. The flanks are much broken, contorted, and cleaved by the primary structure, and many hornblende and quartz veins intrude into them from below. I have seen this effect of the crystalline rocks on mud and clay in old mines; and also in compact clay-soil in contact with schistose rocks.

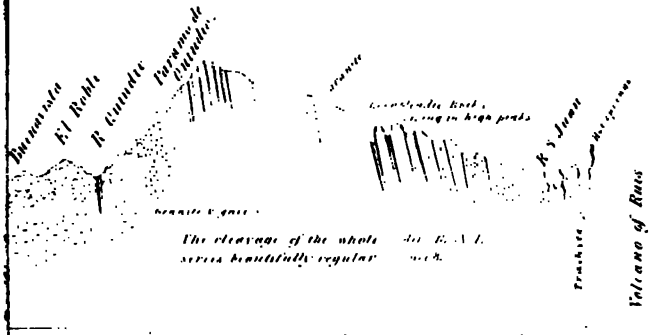
The sections having been carefully made, showing in detail the characteristic phænomena, which are also applicable to similar rocks in other parts of the world, I must beg reference to them for an ocular demonstration of what I have here briefly attempted to describe.

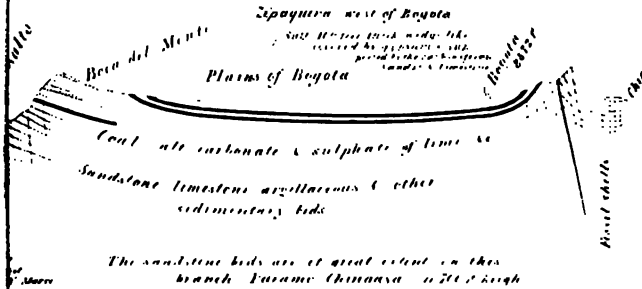
Since I made the first survey of the Andes, I have had the opportunity of making similar investigations in many other parts; and subsequently to my last visit, I have geologically and topographically surveyed the whole Isthmus of Panama; and also many parts of Prussia and other places on this side of the Atlantic; and lately I have visited the clay-slate districts of Wales; and the whole, without exception, present an order of structure and transition of the primary base similar to that observed on the Andes.

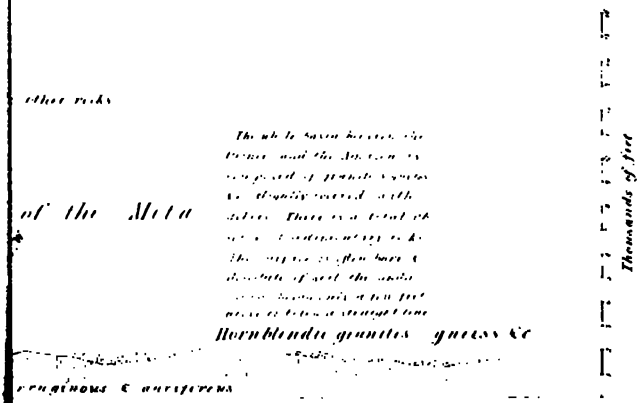
In conclusion, the knowledge of the above phænomena of order, and of the electro-chemical influence going on within the compound mass, will enable us to determine questions connected with mining and unexplored mineral ground, with a degree of certainty hitherto unknown in this most valuable branch of our industry. Besides, without the knowledge of this important subject, the progress of geological dynamics must be slow and very imperfect, as it is, truly, the key by which we obtain an insight into the cause of the great changes which have occurred and still take place on the surface of our globe. These electro-chemical agents are still silently at work, dissolving, recomposing, and cleaving, within the crystalline film that coats the globe; perpetually modifying the compound and rendering it suitable to our wants during all ages of its transformation, and constantly providing inexhaustible stores of mineral wealth for successive generations. These variations, produced by crystallizing forces, which are more universal, more powerful, and as constant as the upward force of the growth of vegetation, cause changes, which, although insensible during the age of man, accumulate and become apparent in long periods of time.

* Proc. Geol. Soc. vol. iv. p. 391 *et seq.*

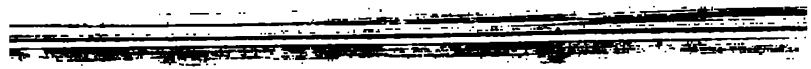
ard from the Pacific.




Sopaquira west of Bogota
Boca del Monte
Plains of Bogota
Bogota East
Coal ate carbonate & sulphate of lime &c
Sandstone limestone argillaceous & other
sedimentary beds
The sandstone beds are at great extent on the
branch Paramo Chimanza
other rocks



Frederic Reece. lith.



3. *Notice of the Occurrence of* COAL *near* ERZEROOM.

[Communicated from the Foreign Office, by order of Viscount Palmerston.]

AN extensive seam of coal has been discovered in the district of Oltoo*, about thirteen hours distant from Erzeroom. The coal is stated not to be of prime quality, containing a good deal of sulphur; and it is slaty, leaving a residue, probably of 12 to 15 per cent. The seam is represented as very broad, and situated on the side of a hill, so that at present it can be worked for the mere labour, and a man in a day can work out 600 okes, or about three-quarters of a ton.

MARCH 27, 1850.

Henry Clifton Sorby, Esq., was elected a Fellow.

The following communication was read:—

On the VENTS *of* HOT VAPOUR *in* TUSCANY, *and their* RELATIONS *to* ANCIENT LINES *of* FRACTURE *and* ERUPTION. By SIR RODERICK IMPEY MURCHISON, G.C.St.S., F.R.S. G.S. L.S., Hon. Mem. R.S. Ed., R.I. Ac., Mem. Imp. Ac. Sc. St. Pet., Corr. Mem. Ac. France, Berlin, Turin, &c. &c.

Introduction.—In surveying the principal localities of those remarkable vents of hot vapour in the Tuscan Maremma, called "Lagoni," "Fumacchi," "Fumarole," "Soffioni," "Mofetti," and even "Volcani †," I perceived that their issue took place upon ancient parallel lines of fracture, along which serpentinous and other eruptive rocks had been emitted. As I am not aware that this coincidence in lines of eruption, acted upon at epochs so remote from each other, has been previously adverted to in any geological account of Tuscany, I will first call attention to the phænomenon. I shall next take this opportunity of expressing my opinion respecting the origin of the "gabbro rosso" of the Tuscans, a rock intimately associated with serpentine; and, after a brief allusion to recent earthquake shocks along the same lines, the memoir will be terminated by glancing at the simultaneous production of great divergent elevations in Italy and in the Alps, after the deposit of the nummulitic eocene formation.

* In my 'Researches in Asia Minor, Pontus, and Armenia,' &c. this name is spelt Olti. In crossing the mountain one or two days' journey to the westward, I perceived that the strike of the vertical strata (which was from W.S.W. to E.N.E.) would directly intersect Oltoo; and these beds afforded the only instance of highly crystalline limestone with corals that I met with in this part of Asia Minor, and are probably connected with the carboniferous deposits.—W. J. HAMILTON, *Sec. Geol. Soc.*

† For Italian descriptions of the Lagoni, see *Gio. Targioni Tozzetti*, Viaggi; *Repetti*, Dizionario fisico, &c. della Toscana, tom. iii. p. 369; *Bartolini*, Atti dei Fisio-critici, tom. vi. p. 335; *Mascagni*, Commentario (Siena), 1779; *Guerrazzi*, Contin. dei Georgofili, tom. ii. p. 435; and *Repetti*, Dizion. fisic. stor. ec. della Toscana, tom. ii. p. 624, tom. iii. p. 374, and Continov. degli Atti dei Georgofili, tom. xi. p. 49.

Hot vapour vents.—If the intensely hot vapour gusts which have issued for centuries from cavities in the rocks of the Tuscan Maremma had been as well known to Dante, as they were to Targioni Tozzetti their graphic describer in the last century, the great poet would surely have selected them as a finer illustration of infernal agency than the feeble "bullicami" of Viterbo *. In our own day the chief features of the Tuscan escapes of hot gases impregnated with mineral acids have already been described by Mr. Babbage in Murray's 'Hand-book of Central Italy,' and subsequently they have been connected with a geological sketch of other parts of Tuscany by Mr. W. J. Hamilton, Sec. G.S.† In order, however, to render my own view clear, I must offer a slight outline of the chief phænomena.

In addition to other substances, the hot vapours of Tuscany are charged with boracic acid, known only elsewhere in the active volcano of Stromboli. For the extraction of this last-mentioned salt, the extensive works of M. Lardarel have been entered upon at the following nine localities: viz. Lardarello or Monte Cerboli, Lustignano, Monte Rotondo, Sasso, Il Lago, Castel Nuovo, St. Federigo, and St. Ippolito. These places are all situated in that elevated northern portion of the Tuscan Maremma which lies on the left bank of the Cecina. Thence the affluents of that river (the Pavone, Posera, Trossa, and Sterza) flow northwards; whilst the Cornia and its feeder the Melia run down to the Mediterranean in a westerly and southerly direction. The tract, penetrated at intervals by the hot gases, has a length of about eight geographical miles from N.N.W. to S.S.E., and a breadth of about five miles from W.S.W. to E.N.E.; the whole being comprised within 43° 8′ and 43° 16′ N. lat.

Subtended generally on the E. and N. by the Cecina, this hilly tract, which is much fissured from N. 15° W. to S. 15° E., is separated on the east from the deep valley in which that river runs by a lofty ridge extending from Monte Castelli on the N.N.W. to the Gerfalco mountain on the S.S.E.; whilst another but lower ridge parallel to the above, is seen upon the western side of the gaseous district passing from Monte Rufoli to Lustignano, whence it slopes down to the sea-coast between Leghorn and Piombino. The gaseous vents occur therefore in an elevated and broken trough, on lines more or less parallel to the older flanking ridges. The general character and age of the sedimentary deposits of this region have been recently explained by myself‡. It is enough then, for my present purpose, to state, that although the adjacent and undulating hills and valleys abound in marls and sands of tertiary subapennine age, and that to the south the lowest member of these accumulations is charged with coal of miocene age, the upland tract now under consideration, and from which the boracic acid fumes issue, is chiefly composed of the rocks called Alberese and Macigno. The latter containing *Nummulites*, represents, in my opinion, the eocene, and the former be-

* See Lyell's Principles of Geology, 7th ed. p. 243.

† Quarterly Journal of the Geological Society, vol. i. p. 296.

‡ Ibid. vol. v. p. 276 *et seq.*

longs to the cretaceous system. Professor Pilla enumerates, indeed, cretaceous fossils found in these hills, whilst the still higher ridge on the east of the tract which terminates southwards in Monte Gerfalco, as well as the ridges of Monte Calvi and Campiglia on the west, are both of jurassic age, the *Ammonites Conybeari*, Sow. and *A. costatus*, Schlth. occurring in them.

All these sedimentary rocks, from the jurassic to those of the eocene group inclusive, have been penetrated, and for the most part much altered, by igneous or plutonic rocks, the greater number of which have a serpentinous character, their prevailing direction being equally N.W. and by N., S.E. and by S. Upon entering this elevated tract from the north, I found that its chief town, Pomarancia*, was situated on a plateau of shelly, tufaceous, yellowish, sandy marlstone —in parts a travertine. This band clearly overlies the subapennine marls of the adjacent hills and valleys on the north, in which the rock salt and springs of Volterra occur, and is probably of the same age as the uppermost yellow marine 'panchina' of Tuscany, or as the lacustrine deposit in the valley of the Elsa, which I have alluded to in a previous memoir †. Charged with land and freshwater shells, this rock is disposed in horizontal masses, and denuded into abrupt escarpments, which in the middle ages formed the natural defences of the old feudal town. This tertiary deposit occupies the tract between the picturesque heights of Rocca Sillana on the east, the hot springs of S. Michele on the west, and Monte Cerboli on the south, where rocks of serpentine and gabbro rise up through strata of whitish grey alberese limestone and some contiguous schists and sandstone. It is near the junction of the intrusive rocks of serpentine with the depositary strata, which are there much contorted and broken, that certain hot springs appear, four of which, at Monte Cerboli, have recently been made known and their contents analysed by Professor Targioni Tozzetti ‡. His observations and analysis are of geological importance, inasmuch as they show that those springs which appear at intervals between Monte Cerboli (Mons Cerberus?) and Lardarello, where the vapours issue, define a line, as he says, from N. to S. (but accurately N. and by W., S. and by E.), and that essentially the springs contain, though in different proportions in each, the same ingredients as the lagoni or vapours to the south of them. Thus, exclusive of organic and bituminous

* Pomarancia is the chief residence of Count Lardarel, the spirited and hospitable proprietor of the boracic acid establishments.

† Quart. Journ. Geol. Soc. Lond. vol. v. p. 294.

‡ Delle acque-termo minerali de Monte Cerboli. Firenze, 1846. Estratta della Gazzetta Toscana delle Scienze Medico-fisiche, An. 4. 2. 1. In this memoir the reader will find indications that the vapours of boracic acid had no issue in the beginning of the sixteenth century. See also notice of this tract by the early geological traveller Targioni Tozzetti (Viaggi), whose descendant, the living Professor of Chemistry in Florence, has also published analytical descriptions of the waters of Mont Alceto, Rapolano, Monte Catini, Castrocasa, Cimiano, and Casale.

Since writing the memoir I have been informed by Dr. Daubeny that the boracic acid vapours contain nitrogen gas — thus sustaining his views on the origin of volcanic action.

matter, all the wells contain chloride of sodium, carbonate of lime, the sulphates of lime, magnesia, and alumina, with boracic and siliceous acids. All of them are charged with carbonic acid gas, and one of them with a minute portion of sulphuric acid gas.

The spot now called Lardarello, where the new establishment has been built, is that portion of the valley rising from Monte Cerboli and watered by the Posera from whence the hot vapours escape by orifices, which, like the mineral springs, mark a line from N. and by W. to S. and by E. (fig. 1). The sides of this valley consist chiefly

Fig. 1. *Lardarello and the Soffioni seen from Monte Cerbero. Looking S. and by E., Lardarello buildings seen $\frac{3}{4}$ mile off.*

a, a. Alberese and macigno. *b.* Gabbro rosso.

of alberese limestone and schists, with some points of protruding serpentinous rocks, the lower slopes being partially covered, as far as observation was possible, with younger marls. But whilst these rocks flank the fissure on the E. and W., it is quite open, as before said, to Monte Cerboli and its hot springs on the N. and by W.: it also leads through undulating ground to Bagni a Morbo, about a mile distant to the S. and by E., where hot mineral waters also exist. The present lagoni are artificially formed on those points where water and earth are applied to the escapes of the intensely hot vapours. Partially repressing the issue of heat, by throwing on earth and clay, and thus controlling the size of the orifices, human agency forms active mud volcanos, the number of which and their successive operations are regulated at pleasure. From the limited space in this valley of Lardarello so irrigated and operated upon, various columns of vapour are seen rising to different altitudes, at different degrees of intensity. This perforated ground is in a continually chaotic state from the countless changes it undergoes; and its outlines are indeed so constantly varying by the formation of fresh outlets of gas, that the traveller who should venture among its mazes without an experienced guide would be exposed to great danger. Even the workmen occasionally lose a leg, and sometimes life, when they incautiously tread upon a covering of earth too thin to prevent their sinking into a hot abyss.

The orifice which I best examined was perfectly circular, about fifteen paces in diameter, and at the most active moment of ebullition. Throwing up large globules from its bubbling surface, the heated matter is ever making an effort to overflow the rim of the little crater*. Wherever the subterranean vapour escapes from a crack more or less vertical, and which presents no impediment, the muddy liquid rapidly attains its maximum heat, which is so intense, that, as M. Lardarel, jun., informed me, no instrument had yet been made to measure accurately the maximum heat beneath the surface†. It is probable that no active volcano exhibits greater heat at any point where a test can be applied. Twenty-four hours of this process suffice to saturate the bubbling mixture with boracic acid, and the stuff is then run off into flat cisterns at a lower level. The fluid is there reduced to a third of its volume by evaporation, hastened by the hot vapour being conveyed in tubes beneath the salt pans, and thus saving the former cost of a great consumption of fuel. After the addition of soda, the desiccation proceeds, and crystals of boracic acid are formed. The violence with which the hot gas issues from any crack, provided it be vertical, is such, that if stones of some weight are thrown upon a narrow gush of it, they are heaved up several feet into the air, and heavy flagstones are required to repress the eruptive agent, and conduct a current of it down to the drying houses and pans.

It is highly interesting to compare the present issues of the hot gases and the forms of the lagoni, as arranged and controlled by man, with their natural appearance upwards of eighty years ago, when examined and described by Targioni Tozzetti. The thick white and hot sulphureous clouds rising by fits and starts,—the occasional jets of liquid rising from the boiling cauldrons,—the large and brilliant globules as they burst,—the circular shapes of the lagoni,—the incrustations of sulphur on their banks,—the crackling of the light, pumiceous and hollow ground under foot,—the conversion of the contiguous alberese limestone, then considered a primary rock, into a farinaceous or mealy state,—the fumes serving as a true barometer to the neighbourhood‡,—the perfect salubrity of the spot to animals, though plants are there withered and blasted;—all these phænomena are nearly the same now as when our predecessor described them. But, on the other hand, some of the former phænomena are no longer recognizable. There is no more a countless number of lagoni. We cannot now, as Targioni did, look into dry cavities from which hot blasts only issued, with noises as if from a hundred bellows, and distinguish them from those holes which were then naturally

* In his description of the Hawaii Islands of the Pacific, Mr. Dana accounts for the absence of active eruption and projection of materials into the atmosphere, by the great dimensions of the chief crater, in which the molten matter having a very wide vent, undulates with little or no noise, and quietly overflows its lip from time to time.

† Targioni Tozzetti, the old writer, does not pretend to have ascertained the extreme heat of the vapour; but Professor Pilla, on what authority I know not, places it at 140° Reaumur.

‡ In rainy weather, or when change is coming on, the vapours cling to the earth with increased subterranean noise, and in settled fine weather they rise to a great altitude.

filled with boiling muddy water, discharging gas; for the manufacturer now utilizes all the hot gas, and by the addition of water makes gaseous orifices into mud volcanos. Nor can we any longer recognize a hot lagone approaching to the diameter of sixty *braccie*, which Targioni gives as the maximum size; still less have we a little island floating in such a hot lake. The noises and reverberations in the caverns, which he compared to the beating of a hundred fulling-mills, were doubtless much more overpowering formerly than now, when the apertures are so much closed in, and the issue so regulated. We learn, however, from the above-mentioned faithful historian two points of importance in the consideration of these forms of volcanic action:—1st. That although the lagoni were then said to be increasing in number, one of the orifices, at Monte Cerboli and another at Castel Nuovo, had ceased to act in his time. 2ndly. That flames were said to issue by night *.

Fig. 2. *Ground plan.*

a, *a*. Alberese and macigno (cretaceous and eocene).
b, *b*. Altered alberese and macigno.
c. Gabbro rosso.
d. Thermal springs.
e. Lagoni or Soffioni.

That a connection exists between the Soffioni and the former geological eruptive agency of Tuscany is apparent, the moment we collate the present and the former phænomena. The inference is indeed determined by an appeal to the very line under consideration (see fig. 2). Beginning at the north and by west, we see at S. Michele a copious outburst of serpentine and gabbro, and with it much contortion and rupture of the contiguous alberese limestone; and just at this junction, the hot springs of S. Michele, celebrated for many ages for their medicinal virtues, have their issue. Proceeding thence over undulating ground, for the most part occupied by tertiary tuff, we again find at Monte Cerboli (Mons Cerberus) on the S. and by E., a like conjunction of similar eruptive rocks and dislocated strata, and with them the issue of the before-mentioned hot-springs. Thenceforward to the S. and by E.,

* Targioni Tozzetti quotes Ugolino da Monte Catini's description of the fumes at Castel Nuovo, near to the baths of Bagni a Morbo, and cites his omission of allusion to those of Monte Cerboli as an indication that the latter have burnt out at that time.

the connection alluded to becomes much more interesting; for, as before said, four hot springs boil up *in the same linear direction*, and it is important to remark, that of these, the spring which is nearest to the lagoni partakes most of their boracic character. In short, the springs and the Soffioni charged with sulphuric, carbonic, and boracic acid, issue upon the very same line; and in following this line a little further to the S. and by E., we reach Bagni a Morbo, where hot sulphureous springs issue from fissures in rocks similar to those of S. Michele and Monte Cerboli. Still further to the S.S.E. the boracic acid fumes reappear in a remarkably picturesque cleft of the rocks of macigno, at Castel Nuovo, where the linear direction of the vents is very striking*.

We have thus along a distance of about six or seven English miles from N. and by W. to S. and by E., the clearest possible evidence that the present hot springs and vapours issue upon a line of fissure, in the alberese and macigno formations, which was formed in very ancient times, *i. e.*, as I believe, between the eocene and miocene periods; the production of such fissure having been accompanied by the outburst of great bosses of serpentine and other plutonic rocks.

By extending this observation I perceived that the other "Soffioni" of this tract exist under similar conditions, showing either the actual outburst of hot springs and vapours along such line of former eruption, or the close parallelism of the two lines of phænomena. Thus, in my journey to the miocene coal tract of the Maremma before described†, I found the little town of Monte Rotondo to be built upon a junction of serpentine with the sedimentary strata it had traversed; and in looking from that spot to the N. and by W., I saw the vapours of the Soffioni, which bear the same name, issuing, like those of Lardarello, from a valley encased in flanking ridges of the same hard rocks. Again, the sulphureous lake, about two miles west of Monte Rotondo, having a major ellipse of north and south, is distinctly a prolongation of one of the numerous cracks extending thence to the N. and by W. towards Lustignano, by which boracic acid escapes.

In mentioning these "Soffioni," Professor Pilla‡ has specially described those of Sasso, and although he has not noted the coincidence on which I lay so much stress, any one who refers to his woodcut representing the issue at Sasso, will see that the line of vapour issuing from cavities is parallel to the main direction of the encasing ridges§. Now, these ridges of alberese and macigno have either a dominant direction from N. and by W. to S. and by E., or are perforated along such line by the serpentine, granitone (greenstone), or other eruptive rocks, including gabbro, to which I shall afterwards advert; and hence it appears, that the ancient lines along which nature expended some of her grandest energies in this region, are also those along which she still manifests the present escape of hot springs and

* This is well described by Targioni Tozzetti.

† See Quart. Journ. Geol. Soc. vol. v. p. 292.

‡ Trattato di Geologia, p. 282. Pisa, 1847.

§ I cannot but express a hope that Mr. Babbage will at some time give to the public a copy of the suggestions he furnished to the Grand Duke of Tuscany, for the extension of the useful employment of these hot gases, which might thus serve to convert a barren tract into a wealthy manufacturing district.

gases. Again, these hot gases still produce, though on a small scale, those conversions or metamorphisms of the strata on the sides of their escape, which the geologist can well understand to have operated more largely and powerfully at that period when great masses of serpentine and other igneous rocks were evolved (or strove to be evolved) under enormous pressure, through the younger secondary and oldest tertiary deposits. At Lardarello, for example, small portions of the ordinary alberese limestone have been and are still converted into sulphate of lime by the action of sulphuric acid fumes; and the schistose calcareous shale is baked by the intense heat into brittle porcelain rock of a red colour. But I would here observe, that in these recent and partial metamorphoses by natural causes, as in those of ancient date, traces of the original lamination or stratification are nearly always perceptible in the lumps or masses so affected or altered.

Gabbro Rosso.—The last observation leads me to offer some remarks on the nature and origin of the "gabbro rosso" of the Tuscans; for after an attentive examination of this rock throughout the tract immediately to the north of the boracic acid country, I feel compelled to express my dissent from the opinion of Professor Paul Savi, in which my friend Mr. W. J. Hamilton in his description of the geology of Tuscany has coincided. The chief masses of "gabbro rosso" lie in the tract south of Pisa, and east and south-east of Leghorn, which is bounded on the north by the valley of the Arno, and on the south by that of the river Cecina. The varieties of this rock are instructively exhibited in the ridges of alberese and macigno, which form the east and west sides of a longitudinal depression occupied by subapennine marls, that extend from Colle Salveti near the Pisan valley on the N. and by W., to the valley of the Cecina on the S. and by E. The direct road from Pisa to the Maremma is conducted along this depression. The westernmost of these ridges, which forms the bold coast, south of Leghorn, containing much granitone, serpentine, and other varieties of eruptive rock, also exhibits, particularly along its eastern face, a good deal of the "gabbro rosso," which, as Professor Pilla informed me, obtained this name from the village of "Gabbro," a few miles south-east of Leghorn, which is built on the summit of a conical hill composed of such rocks;—I say rocks called "gabbro," because I shall presently show, that two rocks of entirely different origin have been united under this one name.

The eastern or inland ridge rises boldly up into the mountains which proceed from the north of Monte Vaso to Castellina Marittima on the south, and it is in reference to this group of hills, on the eastern part of which Monte Catini is situated, that I specially call attention, as it affords ample materials for settling the question which has arisen between Professor P. Savi and Mr. W. J. Hamilton on the one hand, and the late Professor Leopoldo Pilla and myself on the other. The two former have endeavoured to show, that whether in its globular and amorphous form, or in its thin-bedded state*, the rocks they call "gabbro rosso" are metamorphic; whilst Professor Pilla

* See Mr. Hamilton's translation of Savi's description, Quart. Journ. Geol. Soc. vol. i. p. 288.

and myself contend, that the amorphous, variolitic gabbro must have been erupted in a molten state, whether we consider its composition and unbedded condition, or the part it has played in protruding through, overturning, breaking, and altering the pre-existing strata. And although my deceased friend Pilla has to a certain extent published this opinion, he has not sufficiently illustrated his views, and I am therefore the more anxious to do him justice, and to adduce some of the reasons he assigned when we visited the tract together. The opinion of an attentive and lively observer of igneous action like Pilla, a Neapolitan by birth, who during many years was occupied in examining Vesuvius, is surely entitled to much consideration in determining such a question; even had not the physical and geological relations of the phænomenon seemed to me quite conclusive. Between Castel Anselmo and Civita Castellina I inspected natural sections, of one of which I here give a sketch (see fig. 3), where the gabbro had not only penetrated the alberese limestone, but had thrown it off in shreds, contorted fragments, and folds on the sides of the eruption. Now, the red gabbro which had manifestly thus acted was entirely an unbedded, amorphous, felspathic mass, for the most part made up of spheroidal concretions having a variolitic structure, *i. e.* with small pustular or globular surfaces in each of the folds or concentric layers into which the large nodules exfoliate. This variolitic surface was specially pointed out to me by Pilla as a proof of the rock having been in complete fusion; inasmuch as the same forms occur frequently in ancient plutonic rocks and in the modern volcanic products of Vesuvius. The rock is, besides, often cellular and amygdaloidal as well as veined, like some of our earthy Scottish traps, occasionally containing crystals of carbonate of lime, analcime, and also the peculiar mineral caporcianite, a variety of stilbite. Chemically considered, this rock is little else than a variety of greenstone. In other words, it is one of those products, accompanying greenstone and serpentine, which has been much impregnated by iron, and which under the blowpipe melts as easily as wax. This is the "gabbro rosso," which I consider to be a true eruptive rock, and which rises up into

Fig. 3.

a, *a*. Alberese. *b*. Gabbro rosso.

Fig. 4.

a. Alberese. *b*. Alberese with mineral veins. *c*, *c*. Gabbro rosso.
d. Miocene? with alabaster. *e*, *e*. Subapennine.

an amorphous mountain mass at Civita Castellina, where it performs, as above mentioned, the part of an intrusive agent. It there throws off on its eastern summit the alberese limestone in a highly fractured and mineralized condition, as seen in fig. 4. From the natural section

here exhibited, it is certain that this eruption of "gabbro" took place after the consolidation of the alberese and macigno formations, *i. e.* after the younger chalk and older eocene. It is also further evident that another movement of elevation occurred after the miocene period; for not only is the limestone associated with white marls to a great extent loaded with alabaster, which some persons might infer was altered limestone, but the whole of this mass has been considered to be miocene, simply because it dips away from the alberese and gabbro in such inclined strata, and is thus placed in striking contrast with the subapennine or pliocene marls of the valley which surround a boss of "gabbro rosso" in perfectly horizontal and unbroken layers. The altered alberese at Civita Castellina has here and there serpentinous soft bands, and bears a metamorphic aspect, with a slickenside surface, accompanied by cracks and numerous veins of arragonite, all of which specially abound near the junction of the alberese with the "gabbro." Copper veins, however, either traverse the alberese or run down its junction with the gabbro; and are therefore of date posterior to the eruption of the latter. It is indeed the opinion of Pilla, that the copper veins have resulted from the same igneous action which evolved the "gabbro rosso," and are contemporaneous with that rock, whilst other authors contend that they are posterior to it. In traversing on foot the wild ridges which separate Civita Castellina from Monte Catini, where the richest copper ores abound, I witnessed repetitions of the chief phænomena above alluded to, in which, besides "gabbro rosso" and felspathic trap (the epidosite of Pilla), there were other rocks of this class both of greenish and purple colours, which I should class as greenstone and serpentine. All these amorphous masses, however diversified in aspect and structure, seemed to me to form parts of the same eruptive matter which has penetrated the macigno and alberese in lines from N.N.W. to S.S.E.

At Monte Catini, where Mr. Hamilton seems to have most studied it, the gabbro rosso appears in a bold promontory fronting the valley of the Cecina on the south, and Volterra on the east. The chief mass is here the same amorphous spheroidal variolite as in other places. Partially, indeed, it assumes still more a serpentinous appearance; the dull red globular lumps and spheroids being often enveloped in greenish coatings. It is not my province to allude to the splendid veinstones of copper*, occasionally quartzose, which ramify along its edges or through this "gabbro;" I content myself with saying, in reference to the point at issue, that in numerous galleries and cuttings the clearest proofs are exhibited of the homogeneity of structure of the amorphous gabbro, and of the total absence of anything in it like original aqueous deposit. In this respect it bears no resemblance to any other metamorphosed stratum which ever fell under my notice. The variolitic arrangement of the spheroids is very striking. On exfoliation they exhibit the pustules before alluded to on the external surface only of each concentric fold,

* As a wayfaring geologist, I was most hospitably received at his villa by Mr. Sloane, the intelligent proprietor of the copper mines of Monte Catini. The ore is very peculiarly diffused and merits a special study.

and they fall to pieces exactly like "basalte en boule." But besides this rock, which is the "gabbro" proper, and plays the same part in relation to the sedimentary strata as the granitone and serpentine and other adjacent rocks of a similar origin, there is a rock also called "gabbro rosso" by Savi and Hamilton, which abounds on the eastern flank of Monte Catini and other places, which is not only totally dissimilar in composition and form from that which has been described, but which I admit is clearly a metamorphosed stratum.

This is a jaspidified red and green calcareous schist, marked by numerous thin laminæ of deposit, which is evidently nothing more than the argillo-calcareous portion of the alberese or macigno formations, which happened to be contiguous to the true gabbro when the latter was erupted. For it is plain that the amorphous gabbro (as seen in a very clear natural section) has twisted back these finely laminated jaspideous strata upon themselves at a point of eruption, as seen in fig. 5. That in perforating, bending back, indurating, and dislocating the schist, the intrusive matter should have communicated its colour, and to some extent its mineral composition, to the argillaceous and calcareous strata thus affected by it, is nothing more than must be looked for, and is indeed frequently found to be the case under similar geological conditions. This appearance of transition, from what must be granted to be true altered sedimentary layers into the amorphous spheroidal "gabbro," has led Savi and Hamilton to think that the spheroidal red gabbro is simply a still more highly fused or altered accumulation of the same aqueous matrix. When, however, we recede from the immediate point of contact, we have not only very different forms in the matrices of the altered and the eruptive rocks, but an essential difference of composition and structure. Pilla has indeed cited instances just as notable of the conversion or metamorphosis of the strata by gabbro rosso, as by granitic, pyroxenic, and porphyritic rocks*. One of those examples is seen in the spot called Botro del Ribuio near Serazzano, where the spheroidal "gabbro rosso" has thrown the strata of macigno into a vertical position, and has changed them into jaspers of blood-red colour, highly charged with silex and oxide of iron†.

Monte Catini.

Fig. 5.

a. Gabbro rosso. *b*. Altered red schist. *c*. Alberese.

If, indeed, the argument about transitions from the rock which has been the agent of alteration into the strata which are altered, be admitted, we must re-open elementary questions in the physics of geo-

* In his 'Richezza Minerale della Toscana,' Pilla unites the "gabbro rosso" with the other ophiolitic or serpentine rocks, which having acted as partial centres of elevation and eruption, rise up as conical, elongated, and rugged mounts, detached from one another (p. 39). He describes the copper of Monte Catini as lying in a true vein, which has the peculiarity of being contemporaneous with the associated gabbro, both of which are posterior to the sedimentary strata (p. 40).

† Trattato di Geologia, Part I. p. 510.

logy which I supposed were long ago set at rest. We may in that way be led to abandon many conclusions at which we had arrived, in refuting the doctrine respecting certain rocks of Cornwall, Norway, and other tracts which were believed by some authors to prove transitions from granites to slates, and thus to indicate a common origin of these two classes of rock! If this method of reasoning be again entertained (as it seems to me it is by M. Savi), then many of the inferences which geologists have drawn concerning the posterior intrusion of granite and other igneous rocks amid depositary strata will be invalidated. For, although there are numerous examples of such phænomena, which no sceptic can assail, still there are frequent cases where it is impossible to define the precise limit between the erupted molten matter and the altered rock. It is indeed in the very nature of the phænomenon that such should happen, and the time of practical geologists can be better employed than in disputing upon such points. Some persons may indeed argue, that many varieties of traps and amygdaloids were to a great extent evolved from the melting of the pre-existing strata in the crust of the globe, and I am quite ready to admit that such may have been the case. But this admission by no means removes them from that class of true eruptive rocks which, in the eye of the geologist, have acted mechanically and chemically upon the strata they have penetrated; for even some of the lavas of Vesuvius may be, in great part, fused and melted materials, formerly accumulated as marine sediment, which have been transmuted by intense heat under pressure. The practical point, therefore, for which I contend is, that the amorphous and spheroidal "gabbro rosso" of the Tuscans is from its composition, and still more *from the geological part it has played*, a true plutonic and eruptive rock; whilst the red jaspidified schists, which have been also termed "gabbro," are nothing more than sedimentary strata altered by the heat attending the eruption of the adjacent masses.

Lines of former and present disturbance.—As it is along the lines of eruption of the serpentines, greenstones, and gabbro, *i. e.* from N. and by W. to S. and by E., that nature has been repeatedly labouring to evolve heat in the west of Tuscany, so also have the secondary rocks been alineated and altered in this direction. It is on the same line that the granitic rocks of Piombino have subsequently uprisen, the average direction of the whole of the coast of this part of Italy being parallel to it*.

Further, it is on this line that the various Soffioni or vapour volcanos issue, and that earthquakes still most affect the surface. Those who would wish fully to comprehend the phænomena attendant upon the earthquake which last agitated the west of Tuscany, and particularly the tracts south of Pisa, should consult the descriptions of Professors Savi and Pilla. In accompanying the latter from Pisa to Civita Castellina, and in thus passing from N.N.W. to S.S.E. along the depression in the subapennine marls, which lies between

* Pareto, Pilla, and the Italian authors show that the granite of Piombino and Elba cuts through the serpentine.

the ridges above described as penetrated by serpentine, gabbro, and other eruptive rocks, I was struck with the fact, that the most powerful vibratory disturbance occurred in the low hills and hillocks of incoherent materials along this very line. The shocks from north to south being most powerful in this parallel of longitude, it was natural that they should produce the most disastrous effect in that portion of the tract where edifices were placed on slightly coherent marl that rises into hillocks void of lateral support. The buildings which rested on the adjacent harder rocks of alberese, gabbro, serpentine, and greenstone were comparatively unaffected, whilst those which stood on marl had fallen or were much shattered. It is further worthy of notice, that in the deepest denudations amongst the hillocks of marl, particularly near Lorenzana, where the earth opened into chasms, subterraneous waters which had been hitherto imprisoned rose suddenly to the surface; just as if artesian wells had been sunk, and that the overlying crust of a basin had been broken through. Spouting forth sand and mud, these jets of water so threw out solid contents, that when dried up they resembled so many molehills with radii; the centre or box of each wheel-shaped body being composed of concentrically laminated sands, marking the point at which the water issued. These appearances not only served to explain the origin of the larger muddy bosses of similar form, common in the incoherent subsoils of Calabria, which have been so frequently subject to great earthquakes, but may also be viewed as another link which connects the present small disturbances of the surface, with the former powerful subterranean energy proceeding from igneous and gaseous development we have been considering.

Thus, in reference to my preceding memoirs and in reasoning by analogy, we are led to infer, that the great evolution of molten matter in former or plutonic times, accompanied by so much heat and its gaseous attendants as to metamorphose whole mountain chains, was succeeded, as the bottoms of the sea rose, by a considerable diffusion of volcanic materials, chiefly of subaqueous origin, but in part subaërial; and that, finally, the lands assuming their present relations to the sea, the extension of molten matter has been confined to a very limited number of fissures or vents of eruption, many of which have become extinct with the lapse of time. A portion, however, of these eruptions in Europe is still in continuous activity, whether emitting solid matter, as at Stromboli, or hot springs and vapours, as in the Tuscan Soffioni; whilst another portion is intermittent, as viewed in the paroxysmal outpourings of Etna and Vesuvius, the occasional formation of small new cones and craters under the waters of the Mediterranean, and the fitful lines of earthquake shocks with their accompanying outbursts of water.

In viewing the intimate connexion between all these phænomena, and in looking to the powers of the Soffioni of Tuscany, we might perhaps infer, that if these gusts of heat were entirely repressed by closing up the orifices through which they now escape, earthquakes to some slight extent might be expected still more to prevail in the neighbourhood, until the expansive forces were liberated; just as the

most calamitous shocks in Sicily and Calabria have occurred when Etna has been most dormant. Putting aside this speculation, the hot vapours may unquestionably be viewed as the remains of a former igneous action, which I believe to have been incalculably more powerful, not only because it is on the same band or its subordinate parallels that the copious masses of plutonic rocks of this tract and the adjacent mineralized strata occur, but because this line is absolutely coincident with the axis of the Carrara and other marbles and their associated slates and crystalline rocks of the Apuan Alps. Now, as those lofty masses or western Apennines, together with their lower parallels in the Gulf of La Spezia, have been shown to be simply altered strata of jurassic age*; so in extending our observation in the same line further to the N. and by W., we find that serpentinous rocks have there, as in the Tuscan Maremma, burst through alberese and macigno and in much greater volume. In truth, the copious serpentines and their accompaniments in and around the territory of Genoa, have converted the cretaceous strata into rocks having all the appearance of palæozoic slates and flagstones. Other and posterior movements have there also affected, though for the most part mechanically, the contiguous conglomerates and sandstones of miocene age, which on the sides of the pass leading from Genoa to Alexandria occupy very highly inclined positions. The phænomena in the Genovesato and Piedmont, like those in the Tuscan Maremma†, indicate that such beds of the middle tertiary age, whether marine or freshwater, have been dislocated along those lines of disturbance, which at an antecedent period had been marked by the protrusion of the serpentinous rocks in a molten state. In other words, it was by the post-eocene eruption, that the great metamorphosis of the pre-existing strata was caused. A long period of comparative repose followed, one of the earliest operations of which was the accumulation of miocene conglomerates, for the most part made up of strata previously altered by the serpentine eruptions; as seen in the hills north of Genoa and Savona on the one hand, or in the Monferrato (Superga) on the other. Another powerful disturbance subsequently took place, when these miocene beds were thrown upon their edges, or were fractured and highly inclined along the same general lines of fissure, which had been marked by a more intensely igneous activity in the previous or serpentine period.

Although the phænomena chiefly treated of in this memoir have reference to a great band of disturbance proceeding on the whole from N.N.W. to S.S.E. along a length of about 100 miles and a breadth of about 25 miles, a glance at the geological map of Italy by Collegno, combined with my knowledge of the country, has led me to think, that whilst this line of eruption contains within itself minor parallels, there are other and divergent lines, along which similar strata have been affected by the same eruptive rocks. The country of North-western Italy, which comprehends the Genovesato and the

* See Quart. Journ. Geol. Soc. vol. v. p. 266 *et seq.*

† See former Memoir and Section Quart. Journ. Geol. Soc. vol. v. p. 283 to 292.

north of Parma, seems to have been the grand centre of serpentine eruption, from whence such lines radiate, as marked by the protrusion at intervals of igneous rocks and the bands of metamorphosed strata which constitute the loftiest ridges of Italy (see fig. 6, p. 383). In this way, the serpentine bosses of the Apennines, between Bologna and Florence, that trend from N.W. to S.E.—*i. e.* from the region of chief eruption—though divergent from the line of the Apuan Alps, and Tuscan Maremma, are exactly coincident with the major axis of the Apennines or great back-bone of Italy, the culminating points of which, as at the Gran Sasso d'Italia, 9530 feet above the sea, are composed of eocene (nummulitic) and cretaceous rocks reposing on jurassic.

Again, if we turn from the east and look to the other great band of eruption to the west of the coast of Italy, as marked by serpentines protruding through the cretaceous and eocene deposits of Corsica, we see (as graphically laid down by Pareto*) that it marks nearly a meridian line. Looking then at Italy on the great scale, the geologist may, I think, satisfactorily connect its dominant physical features with former causes of upheaval. He sees that, as it is in the highly convulsed and broken-up region where the Apennines bend round to become confluent with the Alps, the greatest masses of serpentine have been emitted, so, exploring southwards from this grand focus, he observes that *bands of the same molten matter have been intruded into divergent cracks and fissures* in the crust of the earth, and extend in long linear directions to the S.E., S.S.E., and S. Geological investigation establishes, indeed, not only this fact, but also the important point, that such igneous matter was simultaneously emitted; since it has alone broken through and metamorphosed sedimentary strata of the same age through several degrees of latitude. Now, as few parts of Italy contain strata of higher antiquity than liasso-jurassic, and as there is no evidence that its submarine accumulations had ever been raised into dry land before the cretaceous and nummulitic rocks were accumulated upon them, we have a fair right to infer, that the linear eruptions of serpentine and their accompaniments of gas and heat, absolutely furnished the Peninsula with those chains of hard and altered strata (each containing subordinate parallels) whose features and contents have been described on a previous occasion. In short, there is no reason to believe, that Italy had any well-defined terrestrial existence until the period of the post-eocene serpentinous eruptions. As Corsica, however, is only the northern prolongation of Sardinia which contains Silurian fossils, and as both islands are characterized by a meridian chain of ancient crystalline rocks, it is clear that a very ancient mass of land ranged in that direction, as further proved by its old cry-

* The reader who wishes to become acquainted with the various lithological characters of the rocks classed under the head of Serpentine, and which were all emitted at the post-nummulitic period, must consult the works of Pareto on Liguria Marittima, and on Corsica, both illustrated by excellent geological maps. Although the Marquis Pareto, following preceding authorities, has classed the nummulite limestone with the chalk, I trust he will now agree with me.

stalline and Silurian rocks being overlaid by palæozoic coal plants and a coal formation*. It is certain, therefore, that the serpentinous eruption there found its issue along a line of fracture coincident with the north and south direction which had been impressed upon these lands at a very remote period—such eruption, though divergent from them, being simultaneous with the chief axes of upheaval in Italy.

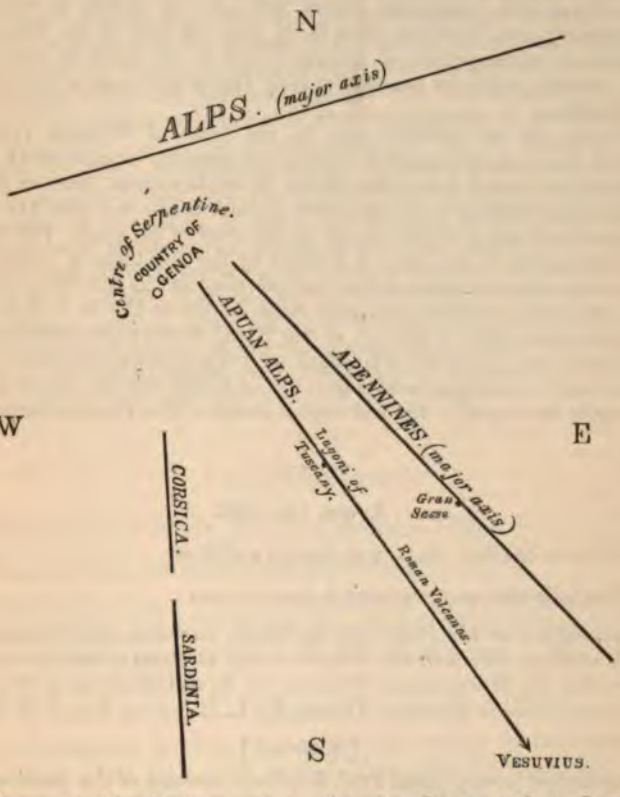
In speaking of divergent lines of fracture and elevation, which offer proofs of simultaneous eruption and dislocation, I am led to terminate my communications on the Alps and Apennines, by calling attention to the great phænomena which are common to these two chains and at the same time distinguish them. To render my idea clear I have annexed the accompanying diagram, fig. 6. Whilst the direction of the chief ridges of Italy is more or less at right angles to the main direction of the Alps, we know that the greatest amount of metamorphism has been impressed on both chains after the nummulitic period; and again, that in both very violent movements took place after the deposition of the miocene tertiary. In the chief

* After this memoir was read, Professor Meneghini of Pisa communicated to me, that Professor Savi and himself had discovered undoubted species of coal plants (*Pecopteris arborescens* and *Annularia longifolia*) in anthracite schists, which on the right bank of the Era near Volterra form the lower part of the "Verrucano," or oldest conglomerate of Italy. A communication to this effect, on the part of his colleagues, was at the same time made by Professor Parlatore at the late Meeting of the British Association at Edinburgh. This important discovery seems to prove that a lower portion of the rocks called verrucano, which have hitherto been considered to be the natural base of the lias, is of the same palæozoic age as the conglomerates of the Valorsine and other places in the Alps. Yet still, in reference to my opinion above expressed, the plants found in Tuscany may either have been derived from lands now submerged, or from adjacent shores, of which the Silurian and ancient crystalline rocks of Sardinia and Corsica are the existing remnants. At all events, no rocks have yet been made known to geologists in Northern or Central Italy which are of sufficient antiquity to have been the *dry land* whereon the coal plants grew, to which Professors Meneghini and Savi have drawn attention.

As Italy is thus connected still more closely with the Alps by the feature of anthracitic coal plants common to both countries, I would here allude to an able recent memoir of Professor Heer (Mittheilungen der Natur. Gesellscht. in Zurich, 1850), in which, specially referring to the case of Petit Cœur in Savoy, he argues, that the plants found there being terrestrial and of the carboniferous æra, the stratum in which they are imbedded cannot be united with that which contains marine liassic belemnites. The general analogical reasoning of this author is so much in unison with my wishes, as expressed in the Memoir on the Alps, Apennines, and Carpathians (Journ. Geol. Soc. Lond. vol. v. pp. 176, 177), that I have only to regret he should have omitted to acquaint his readers, that I drew my inferences solely from the *actual section and the order and position of the beds*. I clearly stated that I did so in opposition to my desire to find the plants and belemnites lying in what might be considered separate formations. With the utmost deference to the value of organic remains, I felt however bound to affirm, that in the example of Petit Cœur, the *physical evidences* seemed fairly to sustain the views of M. Elie de Beaumont and M. Sismonda. At the same time, I did not deny the possibility (though as yet unexplained by an actual appeal to facts) of accounting for this singular collocation by an extremely sharp, inverted curvature, followed of course by powerful denudation. Lastly, I would now observe, that the naturalists who are most opposed to the views of MM. De Beaumont and Sismonda have not visited the locality, which they really must do before they can explain away by fair demonstration what they consider to be an anomaly.

range of the Swiss and Austrian Alps, the greatest changes of metamorphism, elevation, depression, and contortion have been determined upon lines having on the whole an east-north-east and west-south-west direction; whilst in the Apennines the same changes have occurred at the same periods on linear bands trending generally from N.W. to S.E., and even veering round to a meridian strike as they approach the direction of the ancient and palæozoic rocks of Corsica and Sardinia. Notwithstanding, however, their great diversity of direction, the Alpine and the Sardinian lines of active disturbance have

Fig. 6.



each been manifested along primæval coasts, the strata formed upon which contain palæozoic fossils. When, however, we pass from the consideration of events so long past to the contemplation of those agents of terrestrial change which have been most active in comparatively recent times, the Apennines are at once distinguished from the Alps in possessing those truly volcanic phænomena which connect geology and existing history. With the most frequent evi-

dences of recent mutations to an enormous extent in their outlines —*i. e.* since the period of the glacial waters *—the Alps present nowhere the trace of any subaërial volcano; the youngest igneous rocks being those which have traversed the older tertiary deposits of the Vicentin and other tracts. The Apennines, on the contrary, offer proofs, particularly on their western shores, not only of recent oscillations, but also of copious volcanic eruptions. Thus, as was recently shown, subaqueous volcanos were intensely active during the penultimate period, along a band parallel to and flanking the Apennines, which had been raised at a former epoch. After these fires were spent and their dejections raised up into the western lands of the Papal and Neapolitan States, we have no proofs of subaërial volcanicity until Vesuvius burst forth, save the case of the volcano of Latium †, whose period of activity is lost in the maze of time, and the notable examples among the early Greek settlements in the Bay of Naples.

Lastly, let us recollect, that in the tract of Western Tuscany which has been the special subject of this memoir, we also read a most instructive lesson upon the efforts of *subterranean igneous forces to develope themselves at successive periods along one and the same established band of active change in the crust of the globe.* For whilst one extremity of this band is marked by the eruptions of Ischia and Vesuvius, where volcanic action has prevailed in the historical period, we have only to follow such zone from Naples to the N.N.W. to see that it passes along a portion of the Papal States replete with earlier volcanos, and is directly coincident with tracts powerfully affected in much more remote periods, along one of which volcanic action is still partially developed in the hot vapour issues of the Tuscan Maremma.

April 10, 1850.

William Murray, Esq., was elected a Fellow.

The following communication was read:—

Observations on the Discovery, by Prof. Lepsius, *of* Sculptured Marks *on Rocks in the* Nile Valley *in* Nubia, *indicating that within the* Historical Period *the* River *flowed at a* Higher Level *than in* Modern Times. By L. Horner, Esq., F.R.S. &c.

[*Abstract.*]

The author having given Prof. Lepsius's account of the position and character of certain hieroglyphics registering the heights of the river floods, sculptured in the time of Amenemha the Third (Mœris), about 2200 years B.C., on the face of the foundation rock and the masonry of two fortresses which were built by Sesuatesen, predecessor of

* See "Distribution of the Superficial Detritus of the Alps, as compared with that of Northern Europe." (Quart. Journ. Geol. Soc. vol. vi. p. 65.)

† Quart. Journ. Geol. Soc. vol. vi. p. 294.

Mœris, on the banks of the Nile at Semne in Nubia; and having referred to the hypothesis proposed by Prof. Lepsius, in explanation of the great difference (26 feet 8 inches, English) apparent between the highest ancient level of the water of the Nile, as indicated by the uppermost of the markings, and the highest level of the water during the inundations of the present day, viz. that the bed of the Nile in Nubia has been excavated to a depth of 27 feet during the last 4000 years; proceeded to inquire into the physical and geological features of the Nile Valley in Nubia, noticing the power of the stream and the hardness of its bed—including the volume and velocity of the river, its depth and degree of inclination, and the lithological character of the rocks over which it passes. After a lengthened consideration of these important conditions, Mr. Horner arrived at the conclusion that any wearing away of the bed of the channel north of Semne, the site of these ancient nilometric markings, could not have taken place within the historical period. The only hypotheses that in the author's opinion could meet the requirements of the facts observed, would be either the wearing away of a reef or barrier at the place in question,—a process requiring too long a period,—or the existence at some distant period of a dam or barrier, formed perhaps by a landslip of the banks, at some narrow gorge in the river's track below Semne, which in the course of time had again been washed away:—but of the existence of any such contraction of the channel where such a barrier was possible, the author stated there is as yet no evidence; and he concluded by observing, that the conditions attending these markings, at present so enigmatical, offer an interesting problem to any geologist, well-versed in the questions of physical structure involved, who may hereafter visit Nubia.

April 24, 1850.

Douglas Denon Heath, Esq., was elected a Fellow.

The following communications were read:—

1. *On the* Till *near* Wick *in* Caithness. By John Cleghorn, Esq. [*Communicated by the President.*] *With a Note on the* Shells *found in the* Till *by* Mr. Cleghorn. By James Smith, Esq., F.G.S.

[*Abstract.*]

In examining the Boulder Clay or Till that occurs on both sides of the Bay of Wick, as a thick deposit of very hard greyish clay, and in almost every district of the county of Caithness, the author had particularly noticed the fragmentary state of the majority of the contained shells. In accounting for this phænomenon, he considered as inadmissible the action of icebergs grating over the sea-bottom, which has been brought forward by some as sufficient explanation of the existing condition of these shells. The larger and stronger shells would be broken, as is here the case; but the smaller and more

fragile shells also would have been comminuted,—a condition that does not always obtain in the Till, as for instance in the case of the *Turritella terebra*. The author thought, however, that the condition in which small shells and fragments of larger shells, of kinds similar to those of the Till, are found in the stomach of the Cat-fish (*Anarrhicas lupus*), common on our coasts, would be a likely explanation of the condition in which the shells of the Till are usually found.

Note on the SHELLS *found in the* TILL *by* Mr. CLEGHORN. By JAMES SMITH, Esq., of Jordan Hill, F.G.S.

The shells are much broken and water-worn ; I could only identify the following species :—

Dentalium entale, *Gmel.* sp.
Saxicava rugosa, *Linn.* sp.
Mya truncata, *Linn.* (var. Uddevallensis).
Tellina proxima, *Brown.*
——— solidula, *Penn.*
Cyprina Islandica, *Linn.* sp.
Astarte Garensis, *Smith.*
——— Withami, *Smith.*
——— borealis, *Linn.*
Cardium edule, *Linn.*
——— echinatum, *Linn.*
Turritella terebra, *Linn.* sp.

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2. *On the Occurrence of* MARINE SHELLS *in the* STRATIFIED BEDS BELOW THE TILL. By JAMES SMITH, Esq., of Jordan Hill, F.G.S. *With a notice of the Occurrence of* MARINE SHELLS *in the* TILL. By J. C. MOORE, Esq., Sec. G.S.

IN the basin of the Clyde, the Till or unstratified boulder clay generally rests upon the beds of the coal formation, or upon rocks of an earlier date ; and these subjacent rocks are almost always fractured where they are in contact with the Till. There are however exceptions ; sometimes the Till rests upon scratched but unbroken surfaces of those rocks ; and sometimes, but very rarely, we find immediately below the Till beds of sand, gravel, and laminated clay,—fragments apparently of an older alluvial covering, which has not been entirely removed by the cause, whatever it was, which lodged the Till on the surface.

Until the discovery which I am about to communicate, no marine remains had been found in the beds underlying the Till. We had therefore no direct evidence to prove that those beds are of the same age as the deposits which lie above them.

Having been informed by Mr. John Craig, F.G.S., that a bed of shells had been discovered near Airdrie, much higher than any previously found in Scotland, I considered it of importance to ascertain the exact amount of the elevation above the present level of the

sea, as well as the species of the shells, and the nature of the deposit in which they were found. Mr. Craig kindly accompanied me to the locality, which is near the Monkland Iron Works, and about fourteen miles to the south-east of Glasgow.

The shelly deposit in question proved to be a bed of the *Tellina proxima*, Brown (*T. calcarea*?, Linn.), an arctic species, extremely abundant in the Clyde pleistocene beds overlying the Till, and which I had formerly procured from a Brickwork in the same neighbourhood. The shells in the present instance were discovered by Mr. James Russell, an operative miner, in digging a well.

I ascertained the elevation of the place above the summit-level of the Monkland Canal, by barometrical measurement, to be 248 feet, which, added to the height of the canal 276 feet, made the elevation of the surface of the ground 524 feet above the high-water level of the sea.

This is at least 150 feet higher than the highest level at which any shelly deposits have been hitherto discovered in Scotland, and they have only been discovered so high as that level in the two following instances: Mr. Craig found shells near Airdrie*, at the estimated height of 350 feet, and Mr. Prestwich found them at the same height at Gamrie in Banff†.

At the time when Mr. Prestwich made that discovery, it was not suspected that the shells in these very modern deposits differed in any respect from the shells now inhabiting the adjoining seas, and he accordingly named those which he discovered after the recent species which most nearly resembled them. Suspecting that a difference existed, I requested leave to examine them; having done so, I find that they possess the same arctic character that the Clyde shells do, and in particular, that the species which Mr. Prestwich named *Tellina tenuis* is in fact the *Tellina proxima*, the same species as that found on the present occasion. This is a fact of some importance, because it has been supposed by many geologists that none of the shells found in the raised beds in the east coast of Scotland differ from those now inhabiting the adjoining sea.

The most remarkable circumstance attending the present discovery is, that the shells were imbedded in the stratified clay below the Till.

Mr. Russell states, that at the depth of fourteen feet from the surface, after passing through the Till, he came to a bed of brick clay containing the shells, which were therefore 510 feet above the level of the sea. I could entertain no doubts as to the nature of the superincumbent matter, as that part of it which had been thrown out was left lying at the mouth of the well. It was unquestionably the true Till. Indeed, if I had entertained any doubt as to this point, it would have been removed by the discovery of a small granite boulder, which was found about two feet above the bottom of the Till. I may here observe, that granite boulders to the east and south of Glasgow are excessively rare, and very small; I have not seen any larger than a

* See my paper on the Last Changes of Level in the British Islands, Mem. of Wernerian Society, vol. viii. p. 59.

† Proceedings of Geol. Soc. vol. ii. p. 545.

man's head; but as we go to the north-west, they increase both in number and in size. The nearest granitic rock in that direction is at Cruachan, about sixty miles to the north-west of Airdrie.

In the Till itself, organic remains are so rare, that it has been considered by some geologists as altogether destitute of them. There are, however, perfectly well-authenticated instances of the bones of the fossil elephant being found in it, and upon one occasion I found broken and water-worn fragments of shells irregularly dispersed in it*, amongst which I recognised the massive hinge of the *Cyprina Islandica*, Linn. sp., and the stem of a large species of *Balanus*, apparently the same as that figured by Sir Charles Lyell in his paper on the Changes of Level in Sweden†. Both species abound in the pleistocene beds, but neither of them is found in the immediately adjoining sea. The shells lately discovered in the Till by Mr. Cleghorn, at Wick and at Thurso, are precisely in the same state as those discovered by me, namely broken and water-worn. I may add, that they have the same arctic character, for amongst them I observe the *Tellina proxima* or *calcarea*, the *Astarte borealis*, Linn. sp.; and the *Astarte Withami* of my catalogue, so named because the shell was sent to me from Bridlington by the late Mr. Witham of Lartington.

We may conclude from the facts now brought before the Society, that the Till, and the stratified beds which lie immediately below and above it, all belong to the same geological period—to that which immediately preceded the present, and which has been named by Prof. Edward Forbes the Glacial epoch.

I may add, that Mr. Russell states that after passing through the shelly bed of brick clay, he came again to the Till; thus proving indisputably what has always been suspected, that there has been more than one deposition of the Till or boulder clay.

Notice of the occurrence of MARINE SHELLS *in the* TILL. By JOHN CARRICK MOORE, Esq., Sec. G.S. *In a letter to James Smith, Esq., of Jordan Hill, F.G.S.*

"I HAVE two facts to communicate, which have come within my own observation in Wigtownshire, and which will interest you who have paid so much attention to pleistocene geology.

"1st. After diligently hunting the boulder clay, which usually is found to contain only fragments of shell, and that sparingly, I succeeded in finding one perfect valve of *Astarte compressa*, Montag. sp. The spot where I found it is on the west shore of Loch Ryan, about two miles from Stranraer; it was imbedded in the genuine Till or brown sandy unstratified clay, with blocks of transported rocks interspersed through it.

"2nd. Reposing on the Till, patches of a distinct clay containing no gravel or boulders, occasionally occur in Wigtownshire. On one of these is erected the Culhorn Tilework, within half a mile of Stran-

* See my paper in Wern. Memoirs, vol. viii.
† Philosophical Transactions for 1835.

racr ; at this locality the clay contains *Nucula oblonga*, Brown, which appears to have lived and died on the spot ; as in all the specimens the two valves were united, and appear not to have suffered the least abrasion.

"I send you these facts, as they may be of service to you in speculating upon the origin of these beds."

20th April, 1850.

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3. *On the* NEW RED SANDSTONE *of the* SOUTHERN PORTION *of the* VALE *of the* NITH. By ROBERT HARKNESS, Esq. [*Communicated by the President.*]

[*Abstract.*]

THE sandstone occurring in the southern portion of the Vale of the Nith forms the north-west extremity of the great triassic formation which, commencing south of Appleby in Westmoreland, passes northward, having the mountain limestone for its eastern boundary, until it reaches Dumfriesshire. Its western boundary is also mountain limestone until it comes in contact with the eastern extremity of the West Cumberland coal-field, from whence it turns westward, skirting the edge of this formation, until it reaches the sea near to the entrance of the Solway Firth, under which it passes and again reappears in the southern portion of Dumfriesshire.

The eastern limit of the new red sandstone in Dumfriesshire is the parish of Canobie, where it is seen in the bed of the river Esk at Canobie Bridge. Its northern extremity in this parish is met with a little higher up the river at a place called Knottyholm, near to which the Canobie coal-field commences. The new red sandstone forms the southern portion of this parish ; from whence it ranges westward, and passing through the greater portion of the parish of Half Morton, is again seen and worked extensively in the adjoining parish of Kirkpatrick Fleming. The upper portion of this parish consists of mountain limestone, which forms the northern boundary of the sandstone, and this limestone extends for a considerable distance in a southwesterly direction, forming the northern extremity of the sandstone in the parishes of Annan and Cummertrees. The sandstone occupies the whole of the former parish except a small portion of its northern part, and in the latter it is confined to the southern end. Besides the parishes already mentioned, of which it constitutes a part, it occupies exclusively the parishes of Gretna and Dornock which lie upon the margin of the Solway Firth. The parish of Ruthwell, west of Cummertrees, and bordering the Firth, is composed principally of mountain limestone, and it is probable that near here the sandstone again passes under the waters of the Solway before it reappears in Caerlaverock, west of Ruthwell ; and here commences that portion of the new red sandstone to which this account more immediately refers.

In Caerlaverock the eastern limit of this sandstone cannot be as-

certained, on account of a considerable portion of the morass called Locher Moss filling up the interval between the elevations of this locality and those of the adjoining parish of Ruthwell. It is however probable that the sandstone abuts against the whin*, a rock which appears to run seaward, and which is seen in a cutting of the Glasgow and South-Western Railway near the Racks station. This whin appears to be a continuation of the hills of Tinwald, Torthorwald, and Mousewald, which run in a north and south direction. From Caerlaverock the sandstone continues its course northward through the whole parish of Dumfries, from thence passing into the neighbouring parish of Tinwald, but along the whole of its eastern boundary to this parish it is covered by the same morass. On approaching the Bar Hill of Tinwald, which consists of whin, the sandstone takes an easterly direction, and after passing through the southern end of the parish of Kirkmichael is again met with, occupying a considerable area in the parish of Lochmaben. Here it is bounded on the south by whin and mountain limestone, on the west by the whin hills of Tinwald, and on the east, after crossing the river Annan and entering Applegarth, by the same rock in this parish. On the north it enters the parish of Johnstone, and here it has again the whin boundary, which continues through Kirkmichael into the more northern parts of the parish of Kirkmahoe; the latter is principally composed of new red sandstone, and lies south-west from Kirkmichael. After leaving Kirkmahoe it passes under the river Nith and reappears on the high ground at the south-east end of the parish of Dunscore, where it is also bounded by whin. Of the adjoining parish of Holywood, south of Dunscore, the sandstone forms the whole except the western end, which is likewise whin. From Holywood it crosses the river Clenden and enters the stewartry of Kirkcudbright, and after skirting the whin hills of Kirkpatrick, Irongray and Terreagles, and the elevations of the same nature in the neighbouring parish of Troqueer, it again passes under the Nith, south of Dumfries, and from thence the river forms its western limit.

The points of contact between this deposit and the sandstone in this locality are obscured, and the strata themselves in a great measure covered up, by the sands and gravel of the boulder formation and by the debris produced by the decomposition of the whin. There are, however, many quarries and natural sections from whence a knowledge of this formation may be obtained.

In the parish of Caerlaverock the sandstone is wrought at Bankend,

* I have adopted the local term 'Whin' for a rock which is the most prevalent in Dumfriesshire, and to which the name Greywacké was formerly applied. Although the term 'whin' is often used to signify an igneous rock, here it relates to an aqueous one; but from the absence of fossils I have been unable to refer it to any of the accepted geological formations. I learn however from Prof. Sedgwick that in some parts of the southern highlands of Scotland, of which this rock forms a part, he has discovered several bands of fossils, and from them he is induced to conclude that the whole or nearly the whole of these bands are below the Silurian formation. In lithological character the compact whin approaches near to the upper Silurian of Kendal.

at its southern extremity, and near the village of that name. Here it consists of beds of solid rock, each bed being composed of laminæ of different degrees of fineness. The fine laminæ are regular, and seldom exceed a quarter of an inch in thickness; the coarse ones vary from one-third of an inch to an inch, and are very irregular in thickness. The beds separate along the faces of these laminæ, and often where the faces of the coarser laminæ have been exposed the grain is of a rough nature, which makes the rock appear coarser than it really is. The varying thickness of these laminæ also sometimes causes the faces to have a torn and rough aspect owing to their passing into each other. Each of the strata composing the quarry is of considerable thickness, in some cases approaching nearly six feet. The whole of the rock is false-bedded, and more irregular than any other quarry in the district. The false-bedding extends even to the laminæ which compose the strata, some of these having not only different, but even opposite directions. On the whole the inclination appears to be towards the south-west at a small angle. On the north-west corner of the quarry some higher beds, flaggy, more regular in dip, but of small extent, are to be seen. The whole quarry abounds in faults, to which the irregularity of the dip is in a great measure to be ascribed.

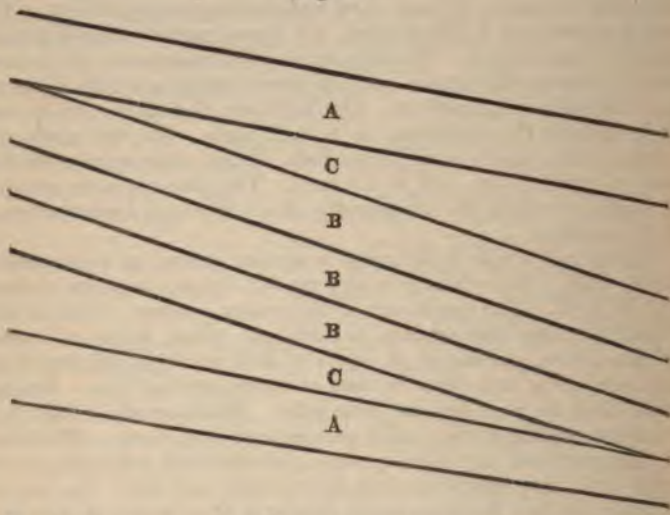
About half a mile to the north is another quarry, at a place called Green Mill. Here the dip is very regular, being at an angle of about 32° W.S.W. The upper part of this quarry consists of beds of thin flags little more than an inch in thickness; these, however, become thicker below, and consist of layers of dark and light red sandstone, separated from each other by lines of brown oxide of iron. Beneath these flags the rock becomes more solid. The faces of the flags have a regular smooth surface and a purple burnished colour. The joints in this quarry are very regular, running almost north and south, and in some cases they have their faces covered with red clay. On the fine faces of the flags footsteps occur, similar to those which are met with in the new red sandstone of Corncockle Muir, but of smaller size.

After leaving the parish of Caerlaverock and entering that of Dumfries, we again meet with the sandstone at the Craigs quarry, about a mile and a half south-west from the town of Dumfries. On the flaggy beds composing the lowest portion of this quarry footsteps of animals are met with.

At Locherbrigs, near the northern termination of the parish of Dumfries, there are four quarries. The higher beds in the most northerly of these consist of flags parted by bands of black oxide of manganese. The thickness of the strata forming this flaggy deposit varies from three to five feet. In some cases the surface of the flags is rippled, the black oxide of manganese rendering this form of surface very distinct. There is a good deal of false-bedding in this deposit, and the dip varies considerably, but on an average the flags incline at an angle of about 22° W.S.W. Below these flags a rock of a fine and uniform texture occurs, having the faces of the strata polished and burnished, and of a purple colour. The thickness of

the beds of this rock is very variable; the dip is at an angle of about 34° W.S.W. In one of the lower beds of this deposit footsteps have occasionally been met with. In the quarry lying furthest to the east the beds are more false than in any of the others, and yet the general dip is the same. This false-bedding will in some cases extend to several beds, above and below which strata occur having an inclination uniform among themselves, but differing from that of the intermediate strata, which latter present great difference of dip, some being more inclined and others approaching the horizontal. (See fig. 1.)

Fig. 1.



The beds A A are such as have the usual dip of the quarry; B B B are more highly inclined, having the false dip; and the beds C C, which are also false, show the manner by which the false bedding is compensated for by the thinning out, or thickening of a bed, as the case may be. Such beds as C C are far from being uncommon in this quarry, even where there is no highly inclined beds such as B B B; in which case they present the appearance of a stratum diagonally divided, rather than the thinning out and thickening of two separate strata.

In that portion of the quarry which lies furthest to the south, the bedding is much more uniform, and the dip, as shown on the faces of the rock, is 34° W.S.W., being exactly that which the other quarries afford when the dip is regular. In this quarry the rock consists of thin flags, under which lies a more compact stone; beneath this, two beds of thick flags occur, and under these the rock again becomes thin-bedded. These different rocks present the same purplish red faces with those of the other quarries, with the exception of the flags

that bear the marks of footsteps. These impressions have a general resemblance to those of Corncockle Muir, near Lochmaben, figured in the twenty-sixth plate of 'Buckland's Bridgewater Treatise.'

From Locherbrigs the sandstone runs northward for about two miles, then taking an easterly direction occupies the southern portion of the parish of Kirkmichael, and crossing the river Kinnel extends itself into the parish of Lochmaben.

It is in the north part of this parish that the quarry of Corncockle Muir, the first locality in Great Britain which afforded fossil footsteps, occurs. Although, strictly speaking, this district is not included in the Vale of the Nith, yet it is occupied by a portion of the same new red sandstone which is found in the neighbourhood of Dumfries, and may therefore be considered along with it. Here the dip of the strata is about 34° due west; and the beds vary in thickness from about a foot to four feet. The faces of the beds are in general separated from each other by very thin layers of clay, and when this is removed they have, in some instances, the same burnished aspect as the faces of the flags of the neighbourhood of Dumfries. It is on these fine faces and on the intervening fine red clay that we meet with the footsteps which have rendered this quarry so remarkable. The general character of the impressions is similar to those which Locherbrigs, Craigs, and Green Mill afford. They are, however, usually larger and more abundant, and do not appear to be confined to any particular bed.

Another quarry is wrought at Templand Village, about half a mile south from Corncockle. The dip is about 30° west. No clay-partings are met with between the beds, nor do any impressions occur.

At Ross, in the parish of Kirkmichael, the sandstone has a south-westerly dip at an angle of about 30°. In the adjoining parish of Kirkmahoe, at Quarrel Wood, the dip is about 20° W.S.W., and the beds vary in thickness from one and a half to four feet.

The sandstone has also been wrought at Milliganton in Dunscore, on the western side of the river Nith. Here the rock is thick-bedded, and approaches in its nature the higher beds of the Craigs quarry.

In a quarry at the eastern extremity of the property of Netherwood, the lower beds have a regular dip towards the south-west at a small angle; these beds are solid and of considerable thickness, and sometimes appear to be cherty, but have the same uniform red colour which prevails amongst the sandstones of this district. In the north-west corner of the quarry are some beds overlying those above described; these are in a great measure false-bedded, and are of less thickness than the underlying strata. At their upper portions they undergo great change in composition, in some cases being mixed with coarse conglomerate. Some of the beds have their lower parts composed almost entirely of this conglomerate, which gradually passes upwards into common sandstone.

Other beds furnish instances of a structure the reverse of this, viz. where the upper part is conglomerate and the lower fine-grained. It also sometimes happens that in one or two of the beds of conglomerate which compose the entire thickness of a stratum, the conglo-

merate will be found rapidly thinning out, and the rest of the bed composed solely of sandstone of uniform texture without any trace of conglomerate. (See fig. 2.)

Fig. 2.

In the highest part, however, of this deposit, the strata are almost entirely composed of conglomerate, and its thickness appears to increase considerably as it proceeds in a south-west direction.

At the Craigs, a short distance above the Craigs quarry, the conglomerate is met with in its greatest development. In this locality three bold headlands occur presenting lofty fronts and perpendicular escarpments to the east, and from this circumstance the locality derives its name. These consist almost exclusively of the coarse conglomerate, and are so nearly related to each other that a geological description of one will also apply to the other two.

Mid Craig is situated about three hundred yards due west from Craigs quarry, and under this craig the rocks of the quarry dip. The lowest portion of it visible consists of a coarse light-red sandstone, which in some places is fully five feet in thickness. The depth of this sandstone and the nature of the rocks which underlie it cannot be ascertained, owing to the debris which occurs at the base of the Craigs. The sandstone is succeeded by a bed of conglomerate about five feet in thickness, and in this conglomerate layers of sandstone are met with rarely exceeding six inches in depth, which thin out very rapidly and again occur at different positions in this bed. A stratum of sandstone about a foot in thickness succeeds this conglomerate, and appears to increase in thickness in the direction of its dip, which is similar to that of the sandstone at Craigs quarry. Alternate beds of sandstone and conglomerate more or less similar to the foregoing occur for a considerable height, until the sandstone disappears and uniform beds of conglomerate alone are met with. The thickness of these conglomerate beds varies considerably, and even some of the individual beds differ greatly in thickness at different places.

The fragments which compose the conglomerate consist principally of whin, both slaty and compact, beside which some portions of syenite and granite are also to be met with. These fragments are all angular, and devoid of the slightest trace of friction or abrasion of any kind. In size they vary from a small pea to about six inches in diameter, and some occur much larger, but on an average about a cubic inch is the size of the greater proportion of the fragments. They are cemented together by a matrix of fine sandstone which is somewhat similar to that occurring in the Craigs quarry.

There are no distinct traces of joints in the conglomerate, and fissures are few and far removed from each other. This almost total absence of joints and fissures seems to be due to the great cohesion and excessive hardness of the conglomerate. When the forces which gave the underlying sandstone its joints and fissures were in action, it is probable that the conglomerate existed, and in a state similar to that in which it now occurs, since to this force the elevation of both the deposits is referable. In the sandstone, its cohesion being but comparatively small and its hardness being much less than that of the conglomerate, the joints and fissures are such as commonly occur. But in the conglomerate, when the elevatory power was sufficient to overcome the cohesion of the rock, perpendicular fissures were produced at such intervals from each other that the faces of the rock were in some instances so far separated that chasms were formed.

The conglomerate is found at other localities in the neighbourhood of Dumfries besides the Craigs. It occurs at the foot of the Dock, at Castledikes, and also at the New Quay. From this latter locality it appears to extend southward, and forms a considerable portion of the western side of the adjoining parish of Caerlaverock, where it is usually covered with till.

At a short distance south of Glencaple in this parish the conglomerate occurs on the shore. Here the direction of its dip is irregular, varying from west to north, but the inclination is uniform, being about 15°. The conglomerate here consists of whin rock, both slaty and compact, syenite, and red granite ; the two latter prevailing to a much greater extent than the former: the whole is cemented together by a fine and remarkably hard, dark-coloured sandstone.

In the coarser kinds of conglomerate the whin rocks occur more abundantly than in the fine varieties, which are commonly composed of syenite and granite in small angular fragments about a quarter of an inch in size, and approaching in form to rhomboids. So angular are these fragments that the fine-grained conglomerate might at first sight be taken for coarse-grained granite. This fine conglomerate is more susceptible of the action of sea-water than that which is composed of the larger fragments, and many places on the shore are covered with fine red gravel, the result of its disintegration.

On the farm of Banks which lies a little to the south-east of the spot where the conglomerate abounds on the shore, it is likewise met with. Here the fine-grained variety is most abundant.

The same deposit also makes its appearance on the banks of the Cleuden, about three miles west by north of Dumfries. At Cleuden Mills, where it is first seen, it offers all the characters of the deposit at Craigs, except that here it appears to be composed of slaty and compact whin to the almost total exclusion of other kinds of rocks.

In this locality the conglomerate is interstratified with beds of fine sandstone, some of which are fully four feet in thickness, and their dip is about 16° south. These beds of sandstone do not appear to have any relation to those already described as occurring in and below the lower portion of the conglomerate at the Craigs. The river, running in a direction nearly west and east, passes over the strata at

almost right angles. From Cleuden Mills upwards to near Gribton Ford, the river flows over this conglomerate deposit.

About a mile and a half north-west from the latter locality, the conglomerate again makes its appearance in the course of a brook on a farm called the New House of Baltarsan, and also at Glengaber, which lies on the west side of the stream. The dip in this locality appears to be in a S.S.E. direction at a slight angle; but there having been considerable local disturbance here after the deposition of the new red sandstone, the direction of the dip varies from south to nearly east.

The conglomerate also occurs at different heights on hills which compose the south-east corner of the adjoining parish of Dunscore; and from thence it appears to range in the direction of the river Nith, but owing to its being covered by till, all trace of it is soon lost.

The beds of sandstone, with which the upper portion of the conglomerate is interstratified, predominate to a greater extent towards the higher portion of the deposit. The conglomerate does not, however, terminate abruptly, for we find fragments of rock amidst the fine sandstone even after the conglomerate ceases to appear in the form of beds. This occurrence gradually becomes rarer as we leave the great mass of conglomerate, and the beds overlying this deposit ultimately consist exclusively of soft fine-grained sandstone.

A little to the south of New House, the farm before alluded to, a quarry of this sandstone has been wrought. At Cleuden Bank, a little to the east of Cleuden Mills, a similar sandstone occurs. Here the dip is the same as that of the beds of sandstone which are intercalated in the conglomerate near this locality, being about 16° south.

At Castledikes, a short distance south of Dumfries, this higher sandstone occurs lying upon the conglomerate; and the road to Kingholm Quay having been cut through it, a fine perpendicular escarpment of rock is obtained. In the lower beds the isolated fragments, already alluded to, are seen; these beds, like their representatives at Cleuden Bank, are thick and soft, and are covered by thin flaggy beds. The dip of the sandstone is towards the south-west at a slight inclination, both the direction and the dip being apparently similar to that of the underlying conglomerate.

This higher sandstone seems to have but a small area in the neighbourhood of Dumfries. It is probable, however, that it occurs to a considerable extent on the eastern side of the adjoining parish of Holywood, where it is covered by a deposit of till. This sandstone is the highest stratified deposit of this neighbourhood, but it does not however appear to belong to the uppermost beds of the new red sandstone formation.

In order to understand the position of this sandstone, it will be necessary to refer to the new red sandstone as it occurs in the neighbourhood of Annan, although this locality is not within the district to which this account is strictly applicable. On the east side of the river Annan there is a considerable amount of sandstone to be met with; which, in the immediate neighbourhood of the town, consists of strata of a red colour and of various thicknesses, interstratified in

some parts with *beds of clay*, some of which are nearly a foot in thickness. These clay beds never occur in the sandstone deposits of Dumfries. In both Lancashire and Cheshire they are commonly met with in the higher portion of the new red sandstone.

On the under surfaces of the sandstone strata about Annan, there sometimes occur marks of the footsteps of the *Cheirotherium* in relief, like those of the Cheshire sandstone, as well as casts of the lines of desiccation. In the adjoining parish of Kirkpatrick Fleming, which lies eastward, the sandstone affords the same appearances. Here the beds of red shale, interstratified with the solid rock, are more numerous than in the immediate neighbourhood of Annan. At the Cove quarry, the sandstone and the shale beds have undergone an entire change both in colour and texture. The sandstone is white and fine-grained, but soft when first quarried; by exposure to the atmosphere, however, it becomes harder. The strata are of different thicknesses, and interstratified with beds of shale of a red and blue colour.

The whole of these deposits east of the river Annan are evidently superior in position to those in the neighbourhood of Dumfries; and this inference is supported by the absence of interstratified beds of clay amongst the sandstone in this latter locality, as well as by the difference of the footsteps. That the higher beds overlying the Dumfries conglomerate were deposited before any of the Annan beds, is certain; but whether at the former place the representatives of the higher sandstones of Annan have been removed by denudation, or whether the lower beds of the former locality have been elevated above the surface of the sea previous to the deposition of the latter, is quite a matter of uncertainty.

The sandstone formation in the neighbourhood of Dumfries may with propriety be divided into three deposits: viz. 1st, the thick-bedded sandstones with their overlying flaggy strata, altogether more than 130 yards in thickness; 2ndly, the conglomerate, 100 yards thick; and 3rdly, the fine-grained soft sandstone covering the conglomerate, and also about 100 yards thick. The lowest and regular beds of sandstone seem to have been deposited by gentle and uniform currents; but after a deposition of a considerable thickness of this sand, there appears to have been slight interruption, during which the sand became more or less consolidated, previous to the deposition of fresh material. In the flaggy beds the interruptions were far more frequent, and another agent, possibly the polishing power of the tidal waves, produced on the surfaces of the flags the burnished purple aspect already described.

That the action of sea-water can produce such an aspect, Darwin in his interesting narrative affords us an example. He states, that not far from the city of Bahia he observed a coating on the rocks of a rich brown colour, composed of ferruginous matter, occurring within the limits of the tidal waves. This coating he refers to the polishing power of the rise and fall of the tidal waves; and as Humboldt states that the same occurrence is met with at the cataracts of the Orinoco, Niger, and Congo, and has referred it to the friction produced by water in motion, it is probable that the bur-

polished aspect of these flags is referable to the same action. As a negative proof in support of this opinion, it may be stated, that footsteps are rarely if ever found on the highly burnished surfaces, a circumstance which may be accounted for by the friction having obliterated all trace of these markings.

The great extent, extreme thinness, and general uniformity of the alternating laminæ of brown and red sandstone composing these flags, indicate a wide and undisturbed tranquillity. The strata which lie above the flags, however, show that this uniform tranquillity no longer prevailed. The false-bedding of the strata, the alternations of fine- and coarse-grained layers, as at Bankend, and their variable thicknesses, indicate the existence of local modifying influences.

The change in the circumstances under which the succeeding beds were deposited, appears to have been gradual and irregular, both from the mode in which the conglomerate occurs at Netherwood quarry (see fig. 2), and also from the interpolated beds of variable sandstone which are met with in the lower portion of the Mid Craig.

The contour of the country surrounding the sandstone on every side, except the south, is such as to show that at the period when this formation was being deposited, the hills of whin on the east, north, and north-east, syenite and granite on the west and south-west, formed the boundary of a bay into which the waters of the ocean flowed. By the force of the breakers against these rocks immense quantities of angular fragments were detached, and afterwards in part carried towards the entrance of the bay by the reflux action of the tide. The afflux of the tide probably transported from the south the larger portion of the sandy matrix of the conglomerate. The sand was probably derived from the coal beds of West Cumberland with their numerous deposits of grit, which must have been exposed at the time of the deposition of the new red sandstone. The local differences also in the composition of the conglomerate bear evidence to the manner of its formation.

At Cleuden Mills we meet with no traces of either syenite or granite, which would have been present had any current prevailed from the south. At the Craigs we meet with them only in small quantities when compared with the conglomerate on the south-west of Caerlaverock. At this latter locality the neighbouring mountain of Criffel, which is situated about three miles westward, has furnished an abundance of materials for the formation of this deposit. The fragments, therefore, which form the Caerlaverock conglomerate, have not come from the same direction as those which constitute this deposit at the Craigs or Cleuden Mills, *i. e.* from the north, but from the west. The base of Criffel, presenting a bold granitic barrier, against which the force of the water exerted itself, supplied a debris which gradually formed a sloping sea-bottom eastward; hence the reflux action of the tide in this locality would be eastward, transporting material in that direction to form the conglomerate of Caerlaverock.

Both the upper and the lower portions of the conglomerate indicate by the occurrence of sandstones that the change of conditions [illegible] gradual; and in the isolated fragments of rock which are met

with in the midst of beds of the upper sandstone, we have proof of the occasional operation of currents transporting matter in a direction opposite to the general prevailing current during this period.

The almost entire absence of the beds of red and white clay which commonly occur in this formation in other localities, may probably have resulted from the currents having been too powerful for the deposition of an argillaceous sediment.

May 8, 1850.

Lord Alfred Churchill was elected a Fellow.

The following communications were read:—

1. *On* Pachyrisma, *a* Fossil genus *of* Lamellibranchiate Conchifera. By John Morris, F.G.S. and John Lycett, Esq.

Among the fossil shells of the oolite undescribed or imperfectly known, is one, only recently discovered, which is remarkable as presenting characters tending to approximate certain known genera heretofore widely separated. The locality of this genus is one peculiarly rich in the remains of Testacea. These will be illustrated in a forthcoming memoir to be published by the Palæontographical Society. The locality belongs to the Minchinhampton district of the great oolite formation, the geological position of the shell being as follows. About 70 feet above the Fuller's earth is the base-line of a series of limestone beds, which have an aggregate thickness exceeding 20 feet; the lowest bed is a calcareo-siliceous rock, of a cream colour, exhaling an argillaceous odour when breathed upon, and is peculiarly compact and homogeneous in its structure. Its two divisions have a united thickness of 5 feet. The beds above this have a browner aspect, are usually less compact and homogeneous, and are for the most part destitute of organic remains, although locally these are met with in some abundance.

Pachyrisma occurs in a vertical thickness of only half a yard; it occupies the upper 9 inches of the lowest or white bed, and the entire thickness of the superimposed browner bed; the shells are clustered together in great numbers, the valves being both separated and in apposition; and it is worthy of notice that they constituted almost the sole testaceous animals within the narrow limits of their habitat; no other bivalve is found here, and the univalves consist only of a few casts of two species of our new genus *Purpuroidea* and two of *Natica*.

The locality in question having been under our notice for some years, we are enabled to state, with a near approach to certainty, that the area wherein *Pachyrisma* is clustered occupies but a few square yards, and that beyond that space it is rare. On stepping forty yards to the northward, where other excavations are in progress, we find the same bed of white limestone, the upper part of which likewise contains

a few valves of *Pachyrisma*; but the nine-inch overlying and fossiliferous browner bed has altogether thinned out and become lost, the upper and barren limestones reposing immediately upon the white bed. We may then venture upon the inference, that the causes of whatever nature, which produced the cessation of marine deposits for a period at this place, were likewise coincident with, and perhaps conduced to, the extinction of this mollusk. The interval which elapsed between the completion of the nine-inch brown bed and the commencement of that next above, marks its upward limit, but the associated univalves survived these changes and are met with occasionally much higher in the series.

The substance of the test of *Pachyrisma* is converted into crystalline carbonate of lime, and owing to the hardness of the investing stone it is seldom that a specimen can be detached in an entire condition; in the white bed indeed it is impossible to do so, but the browner bed fortunately, being more arenaceous, has softer portions which yield to the knife, and have enabled us by dint of perseverance and the unavoidable destruction of many fine specimens, to disclose the characters of its interior in a satisfactory manner.

Pachyrisma*, Morris and Lycett, 1850.

Gen. Char. Testâ oblongâ, cordiformi, æquivalvi, valdè inæquilaterali, crassissimâ, læviusculâ aut concentricè striatâ; umbonibus prominentibus, anticè recurvis; carinâ obtusâ, dorsali, posticâ; ligamento externo, crasso, subelliptico, umbones versus bifurcato. Dente cardinali in utrâque valvâ magnâ, obtusâ, irregulariter conicâ, et dente parvo anteriore in valvâ dextrâ; impressionibus muscularibus duabus; posticâ in laminâ auriformi lævatâ et concavâ sitâ; anticâ oblongâ, excavatâ, processu dentiformi supernè instructâ.

An oblong, cordiform, equivalve, inequilateral, thick shell, with prominent recurved umbones, and an obtuse posterior dorsal keel; ligament large, external, somewhat elliptical, and bifurcated towards the umbones. A large obtuse conical cardinal tooth in each valve compressed laterally; the right valve has a small accessory tooth placed upon the anterior margin of the pit which receives the large tooth of the other valve. Muscular impressions two; the posterior one supported upon a raised, projecting, and concave auriform plate; anterior impression large, deeply excavated, of an oblong form, and with a small tooth upon its upper margin.

This shell is remarkable for the projecting and solid character of the hinge apparatus, together with its general massiveness. These features are in striking contrast with the attenuation of the posterior side; this latter portion is consequently seldom well-preserved, although the internal elevated auriform processes must have contributed to strengthen this part. The large tooth in each valve projects nearly at a right angle with the plane of the shell, and is bordered by a large and deep pit to receive the tooth of the opposite valve; the small dentiform processes, bordering the anterior muscular impressions, are just in contact when the valves are closed; that of the left

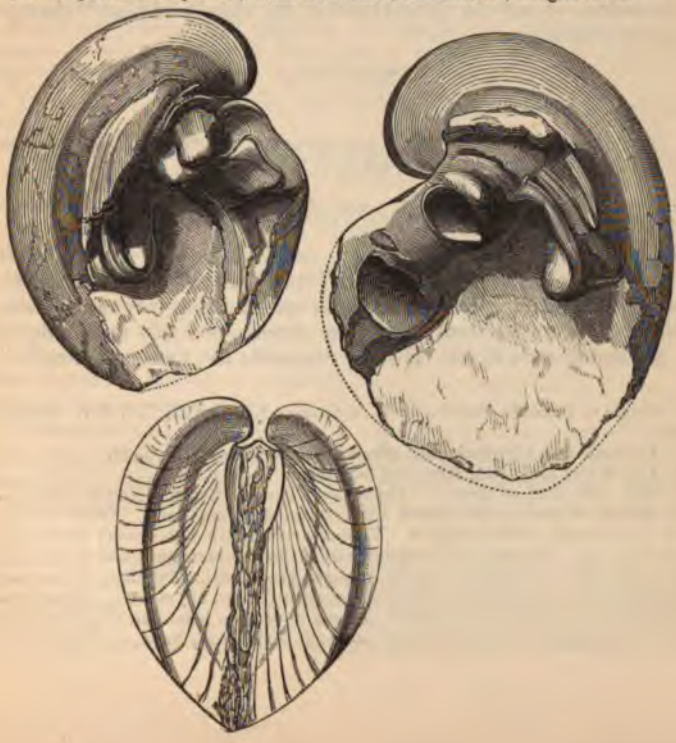
* παχὺς, *thick*; ἔρεισμα, *support*.

valve being received into a small depression above the corresponding process of the right valve, the tooth of the right valve resting within the muscular depression of the opposite one. The thickness of this portion of the test is such, that in an individual which measured six inches across, it was upwards of three-quarters of an inch.

This shell has some affinities with *Isocardia*, *Opis*, and *Megalodon*; the latter of which it appears to represent in the jurassic period, and might with it constitute a family, "*Megalonidæ*." It is distinguished from *Megalodon* by the cardinal tooth in the right valve not having been divided as in the latter genus. *Megalodon* has the anterior muscular impression inserted on a somewhat raised or lamelliform plate; but it has however a slightly raised plate for the posterior muscle, or rather the latter may be said to be bordered interiorly by an obtuse angulated ridge. From *Opis* it is sufficiently distinguished by the character of the dentition. The dichotomous ligament resembles that of *Isocardia*, and when viewed anteriorly it reminds us of the recent *Isocardia cor* with its large and graceful diverging umbones. *Pachyrisma*, then, may be described as a *Megalodon-like* shell, the dental characters of which, however, are peculiar, combined with the external figure of *Isocardia* and *Opis*.

Example. PACHYRISMA GRANDE.

Testâ cordatâ, elongatâ; carinâ obtusâ, dorsali, posticâ, latere antico brevi; latere postico profundè depresso; striis numerosis, concentricis, irregularibus.



Shell cordate, with an obtuse prominent posterior dorsal keel; posterior side deeply excavated; striæ numerous, concentric, and irregular.

In young specimens the form is less gibbose; the small dental processes are very distinct, but the large tooth has little of the importance which it afterwards attains, it not having acquired the conical projecting form as in the adult state.

This shell does not appear to have been described, although it closely resembles a figure published by Catullo * of a cast of a shell named *Cardium triquetrum* by Wolfen †, from the jurassic strata of Antello near Cardonino. The shells figured by Pusch, Polens. Paléont. t. 7. f. 8, 9, under the names *Isocardia exaltata* and *I. ventricosa*, have some affinity with our shell, and may belong to the same genus.

This shell has been provisionally referred to *Cardilia* ‡, but having been enabled, by the kindness of Mr. H. Cuming, to examine specimens of that interesting genus of M. Deshayes, we are enabled to state that the position of the ligament in the two genera is very distinct; in *Pachyrisma* the ligament is external, in *Cardilia* it is internal, seated on a somewhat complex spoon-shaped tooth; the position of the posterior muscle is however in both genera very analogous, being placed in *Cardilia* on a prominent laminar plate, representing the auriform process which supports the same muscle in *Pachyrisma*.

Locality.—From the Great Oolite in the vicinity of Minchinhampton and Chalford.

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2. *Observations on* Dudley Trilobites. Part 2. By Thomas William Fletcher, F.R.S., F.G.S. &c.

Genus Cybele.

Two species of Trilobites belonging to the interesting genus *Cybele* of Lovèn § are occasionally found at Dudley, the *C. punctata* and *C. variolaris*; perfect specimens of either species being very rare. These species were figured from Dudley specimens, probably then unique, by M. Brongniart, in his 'Histoire naturelle des Crustacés fossiles,'

* Saggio di Zoologia Fossile, de T. A. Catullo, t. 1. f. D, E, F, f. 2 A. Padua, 1827.

† Abhandl. vom kärnthenschen pfauenschw. Helmintholith, p. 48.

‡ Annals and Mag. Nat. Hist. 2nd Ser. vol. ii. 1848, p. 258.

§ Thus described by Lovèn: "Caput breve latum. Scutum centrale sublunatum, latum. Sutura pone oculum subrecta, ad angulum ducta. Oculi minuti, arcu infraorbitali elevato, angusto. Thorax articulis (in unâ specie) duodecim. Terga convexa. Pleuræ sulco longitudinali in partem anticam divisæ syndesmalem breviorem, et posticam, majus minusve productam. Pygidium thoraci ex parte conforme, minutum, ex articulis numerosis (ex. gr. 16) coalitis, quorum basales aliquot majores, pleuris prædíti, reliquis in caudam lanceolatam arctius connatis."—Ofversigt af Kongl. Vetenskaps-Akad. Förh. 1845, No. 4, p. 110.

both being included under the name *Calymene variolaris*, although parts of his description appear to be applicable to either species*.

CYBELE PUNCTATA, Wahlenberg, sp. PL. XXXII. figs. 1–5.

Sir R. I. Murchison and Professor Burmeister were acquainted with the caudal shield only of this trilobite; and Dr. Buckland, in his 'Bridgewater Treatise,' appears to have repeated the figure given by M. Brongniart, to which he has assigned the name of *Asaphus tuberculatus*.

SYNONYMS.—*Entomostracites punctatus*, Wahlenb. 1821, Act. Soc. Sc. Upsal. vol. viii. p. 32. t. 2. fig. 1.
Calymene variolaris, Al. Brongniart, 1822, Crust. Foss. tab. 1. fig. 3 A.
Calymene punctata, Dalman, 1828, Palæad. p. 47. tab. 2. fig. *a–g*.
Calymene punctata, Murch. Sil. Syst. pl. 23. fig. 8.
Asaphus tuberculatus, Buckl. Bridg. Treat. pl. 46. fig. 6.

General form ovate; length nearly twice the width; head and tail about equal, excluding the terminal mucro. Thorax nearly half the entire length of the animal. Cephalic shield semicircular, but gibbous in front; its posterior angles produced into extended spines; its length equal to about half its width; its surface coarsely granulated with large tubercles, each with a minute perforation or puncture (Pl. XXXII. fig. 9 *b*), as first observed by M. Brongniart.

Glabella pyriform and gibbous, overhanging the slight anterior margin, nearly spherical in front, where it has a distinct border of large tubercles (Pl. XXXII. fig. 1), and narrowing backwards to half its front width, its base being less than one-third of the entire width of the head.

Two or three large tubercles, arranged on each side of the lower half of the glabella, occupy the situation of the lateral lobes, the furrows between which are not visible; the axal furrows are deep, curving outwards in front, and thence confluent with the deep sulcation which separates the cheeks from the margin of the head; the latter is broad, and its sides have two distinct rows of tubercles.

The course of the upper part of the facial suture is not clearly indicated in the specimens before me, but it probably runs below the front margin, and parallel with the front of the glabella to the eyes; from thence its course is outwards to a point somewhat in advance of the posterior angle of the cephalic shield.

A flattened space bordered by a row of tubercles surrounds the peduncular eyes, which are moderate in size, but prominent, and placed considerably apart, occupying nearly the centres of the convex and tumid cheeks; the distance of the eyes from each other exceeds the

* Brongniart's diagnosis, "angulis externo-posticis in mucrone productis;" and description of the cephalic shield, "sur leur angle extérieur une sorte d'appendice qui se prolonge sur les côtés de l'abdomen, jusque vèrs la sixième articulation," are clearly applicable to the *C. punctata*. His description of the caudal shield applies rather to *C. variolaris*, as he compares it with that of *C. Blumenbachii*.

extreme width of the glabella; the eyelid is tubercular, and the lentiferous surface smooth.

The triangular cheeks are produced backwards, their extremities terminating in prolonged spines.

The neck-furrow is continuous; and the strong neck-lobe, broadest in the centre, is smooth, but has a tubercle at each extremity.

Hypostome ovate, rhomboidal, subtrilobed, tubercular, and surrounded by a sinuated border; its convex extremity very broad, and its cucullated tip abuts against a large tubercle placed upon the anterior margin of the head (Pl. XXXII. fig. 1*a*).

Thorax of eleven rings, its convex axis or central division somewhat narrower than the pleuræ, and separated from them by deep axal furrows. Two tubercles occur upon each of the axal segments, one at each end. A spine is placed upon the seventh, and another upon the tenth segment of the axis.

The pleuræ, usually covered with small tubercles, are horizontal halfway, then strongly curved downwards, and slightly bent backwards; their edges sharpened in front, and their terminations bifid or notched, and tubercular.

Tail long and acutely triangular, terminated in an extended mucro; its axis, tapering backwards to its acute termination, is of less width than the lateral parts, and is composed of about thirty distinct rings. Its centre is smooth and has about seven tubercles prominent and distinct, four rings intervening between two tubercles. The articulating edge is broad.

Eight strong ribs on each side gradually decrease in size as they approach the caudal termination, the anterior ones curving backwards; they are separated by deep furrows, and a distinct tubercle is placed upon the upper and inner end of each.

CYBELE VARIOLARIS, Brongniart, sp. PL. XXXII. figs. 6–10.

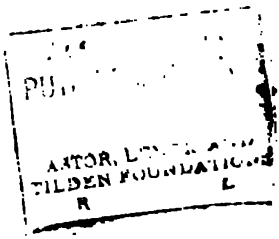
This species is figured in the 'Silurian System,' where it is inadvertently represented as having thirteen body-rings*. Burmeister being unacquainted with the form, and misled by the inaccuracy of the figure above referred to, was induced to consider it as a *Calymene*.

SYNONYMS.—*Calymene variolaris*, Al. Brongniart, 1822, Crust. Foss. tab. 1. fig. 3 B.
Calymene variolaris, Murch. Sil. Syst. 655, pl. 14. fig. 1.
Phacops variolaris, Emmerich, Trilob. i. 20. 4.

A description of this species having been given by my friend Mr. Salter in the 'Memoirs of the Geological Survey,' vol. ii. part 1. p. 344, it will be sufficient to notice its chief points of difference from that last described.

The cephalic shield and thorax have a general similarity to those of the preceding species; but the glabella is rather more prominent

* A recent inspection of the specimen figured by Sir R. I. Murchison from the cabinet of Mrs. Downing, of the Priory near Dudley, enables me to state that it has eleven body-segments.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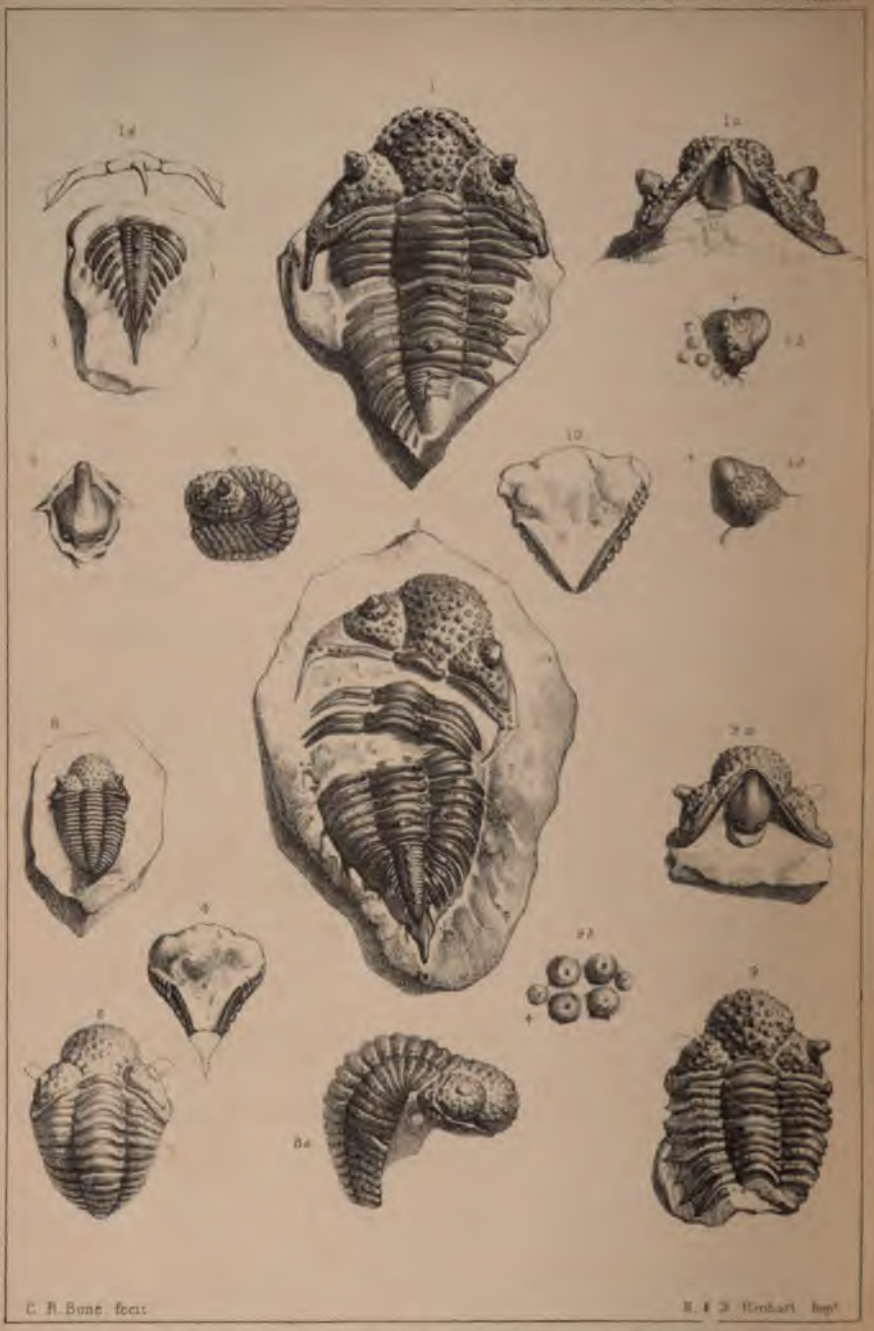

Figs. 1–5. Cybele punctata, Wahl. Figs. 6–10. C. variolaris, Brongn.
The figures marked + are magnified 3 times.

and gibbous in front, and its border of tubercles less distinct; while the posterior angles of the cephalic shield are obtuse, and not produced into spines; each angle is ornamented with a cluster of tubercles, and occasionally terminates in a single large tubercle.

The tail is convex and triangular, its length and breadth about equal, and its axis of ten rings much narrower than its lateral portions, and gradually diminishing to its blunt apex. Seven broad ribs on each side are strongly arched downwards, and bent backwards; the posterior ribs are rounded off at their extremities, and extend below the blunted axal termination. Each lateral rib has a tubercle at its origin.

The upper ring of the axis has usually a single large tubercle upon its centre; the second has a central punctum or slight depression between two large tubercles; the remaining rings having alternately a tubercle and a punctum between two tubercles, except the three posterior rings, which have each a single tubercle only.

Varieties.—The front of the glabella is more gibbous in some specimens than in others, and the markings upon the tail are not quite constant.

EXPLANATION OF THE PLATE.

Figs. 1, 4, 6, 9 and 10 are from the rich cabinet of my friend Mr. John Gray of Dudley; 7 and 8 from the collection of Mr. Charles Twamley, to whom I am indebted for their use; and the remaining specimens are from my own collection.

Fig. 1. *Cybele punctata*, full-grown.
Fig. 1 *a*. The same specimen, under side of the head showing the hypostome, and the tubercle against which it abuts.
Fig. 1 *b*. The eye, magnified, upper side.
Fig. 1 *c*. Ditto, ditto, lower side.
Fig. 1 *d*. The tenth thoracic segment with its spine.
Fig. 2. The same species, adult specimen.
Fig. 3. Ditto, the tail.
Fig. 4. Ditto, the under side of the thorax and tail, to show the bifid or notched terminations of the pleuræ, and the manner in which they are applied to each other in rolling up.
Fig. 5. Ditto, the hypostome; the hooded tip is slightly recurved.
Fig. 6. *Cybele variolaris*, young specimen.
Fig. 7. Ditto, rolled up.
Fig. 8. Ditto, nearly full-grown.
Fig. 8 *a*. Ditto, a side view of same specimen.
Fig. 9. Ditto, a fine specimen; the thorax is slightly bent backwards; it shows the sharpened front edges and notched terminations of the pleuræ.
Fig. 9 *a*. Ditto, the under side of the head of the same specimen; the hypostome is not recurved at the tip, but regularly convex.
Fig. 9 *b*. Ditto, a few of the tubercles with a punctum on each, as mentioned by Brongniart.
Fig. 10. Ditto, an under view, showing a similar structure to that represented at fig. 4.

3. *On the* Geology of Spain. By Don Joaquin Ezquerra del Bayo.

[Communicated by Sir R. I. Murchison, V.P.G.S.]

In order to give a general idea of the geological constitution of our country, it may be considered as divided into three principal divisions, viz. the Crystalline or Gneissoid formations; the Transition formations; and the Secondary. The first predominate almost exclusively in the western portions (not including Portugal), in the whole of the ancient kingdom of Galicia, and extend through Astorga, Zamora, Salamanca, Placencia, Cáceres, Mérida, Lleréna, Aracéna, and Rio Tinto, to the north of Seville and to the neighbourhood of Italica, the birth-place of the Emperor Trajan, now called Sancti Ponce. It must however be observed, that as yet, for want of detailed observations, we have no definite lines to mark the limits of the three formations above mentioned. We can only say that the gneiss rocks occupy about a fifth of the surface of the soil, extending longitudinally from north to south, but throwing out, as it were, ramifications towards the east.

These gneiss rocks are probably secondary or primary formations, altered by the plutonic rocks which have penetrated them. These are generally ordinary granite, more or less coarse-grained, and sometimes traversed by veins or dykes of porphyritic granite. Only at the northern extremity, viz. between Aracéna and Lleréna, in the villages of Zufre and Santa Olalla, is a great syenitic outburst visible.

The most important of these granitic ramifications to the east is that which passes by the Sierra de Gridos, Sierra d'Avila, and the Guadarrama, to Somo Sierra, in a direction from south-west to north-east. The great granitic outburst of Truxillo and of the mountains of Toledo does not extend so far to the east. A third, which is not so well marked as the other two, *i. e.* does not appear on the surface with the same continuity, is that which has probably given its present form to the Sierra Morena. It terminates at Linares, in the province of Jaen.

The gneiss rocks in Spain do not generally abound in metalliferous deposits. There are some however of considerable importance. All the copper deposits of the district of Rio Tinto occur in talcose schist, in the vicinity of the granite. The famous mines of Guadalcanal and of Cazalla (now exhausted) are opened in chloritic schist, not far from the syenitic outburst. The rich argentiferous veins lately discovered at Hiendelencina, in the province of Guadalaxara, traverse the real gneiss, and are also not very distant from the granite of Somo Sierra.

The plutonic rocks themselves are still less rich in useful metals compared with their great development. The most important deposit in a rock of this character is the great system of lead and copper veins in the district of Linares, both for the abundance and excellent quality of the minerals. The granitic rocks in the neighbourhood of Monterey in Galicia contain a small quantity of tin, as well as those of Carbajosa and Carbajoles, near Zamora, on the frontier of Portugal.

To this last formation must also be referred the carbonate of lead and the antimonial-ochre of Losacio, in gneiss entirely surrounded by granite. These rich and abundant minerals of Losacio have not yet proved profitable to the speculators, for want of an economical method of carrying on their operations. The auriferous sands of Galicia, which the Romans worked on so large a scale, and from which the inhabitants still obtain a considerable revenue by washing, and those of the Guadiana and of the Tagus, which are slightly worked in Estremadura, are all derived from the disintegration of the granitic rocks. The auriferous sands of the Darro and the Gerril, sung by the Arab and Andalusian poets, are not worth mentioning; they are very poor, and are not derived from the same source.

The oldest sedimentary or transition rocks, in their different stages, the present forms of which are owing to volcanic eruptions, are in Spain most rich in mineral wealth. The whole range of the Cordilleras of the province of Granada down to the sea, and almost the whole coast from near Gibraltar to beyond Carthagena, belong to this period; consisting of slates, argillaceous schists, and mountain limestone, or rather metalliferous limestone. Fossils are very scarce. The Silurian formation is well characterized in the Sierra Morena, from Santa Cruz de Mudela to Almaden, with its remarkable deposit of Cinnabar. It also occurs in the mountain-chain of Asturia, which contains coal of good quality.

The secondary formations, which are shut in between the older rocks and the sea, occupy a great extent in the centre of Spain, extending to the north and to the eastern coast. The greater part of these secondary rocks belong to the Oolitic and Cretaceous periods; all the members of the series are fully developed except the Muschelkalk.

The Devonian formation is very limited. Some traces of it occur in the centre of the Asturias, and a still larger development occurs in the northern part of the province of Léon, which extends as far as Galicia, following a line parallel with the mountain-chain of Cantabria. In both these localities the Devonian rocks abound with coal of an excellent quality. That of the Asturias, which was already known at the close of the last century, not only in the Devonian, but in other formations, will hardly stand in competition with other coals, unless the company by which it is worked agree to lay out larger sums in working it. That of Léon is more easily obtained, and although it has only been known for a few years, it is already the source of considerable industry in Castille. It is taken to Madrid for the cast-iron foundries and other works, as gas-lighting, &c.

On the Silurian rocks of the Sierra Morena, which we have alluded to, proceeding towards the south, reposes the great coal formation of Espiel and Belsuez, which may be called the basin of the Guadiato, the river by which it is traversed. This formation may be traced for a distance of fourteen leagues from west to east, and extends to within three leagues of Cordova. At Villanueva del Rio, on the right bank of the Guadalquivir, eleven leagues north-east from Seville, is a small basin of coal, extending over nearly a square league of ground. This

coal is not of very good quality, being friable and dusty; nevertheless, owing to its situation so near the river and Seville, many thousand quintals are annually extracted. This is the whole extent of the true Carboniferous system in Spain.

The New Red Sandstone formation contains an extensive development of the Zechstein limestone, which forms almost the sole constituent of the Sierras of Alcazar, of the Sagra, of Cazorla, and of Castril, in the provinces of Jaen, Albacete, and Murcia. The *marnes irisées* have not yet been clearly made out; this is a great deficiency in our geology. There may be perhaps some traces in Moncayo, near Calcena in Aragon, and also in the mountains of Léon, and possibly in the province of Guadalaxara, towards Tamajon, with slight traces of coal. It is said that in La Mancha (now the province of Ciudad Real) the zechstein occurs with its *marnes irisées* and *todt-liegendes*, resting against the northern slope of the Sierra Morena; I have not seen it. At San Juan d'Alcaraz, in the Sierra of the same name, near the village of Riopar, the marls and dolomites are well characterized, and contain a rich deposit of Calamine, the working of which is every day becoming more productive. I think I have discovered the Kupferschiefer of the Germans near Archidona, between Sierra de Lucena and Sierra d'Antequera.

The Jurassic or Oolitic formations constituted, to all appearances, the bottom of the sea during the cretaceous period, inasmuch as it everywhere rises above the surface when the cretaceous formation is interrupted. There is, however, a considerable extent of it exposed, as *e. g.* the whole mountain range, which, commencing near Burgos, continues towards the east through the province of Soria, as far as Moncayo, and thence into Aragon, passing near Arina, as far as Feruel. This ridge of oolitic rock is slightly interrupted by the chalk and tertiary beds, but it again appears in the kingdom of Valencia as far as the town of the same name; so that, in fact, the oolitic formation can be traced from Valencia to Burgos for a distance of 180 Spanish leagues (900 kil.) forming an obtuse angle at the culminating-point of Moncayo. I have observed the same beds at Siguenza and Torremocha, in the province of Guadalaxara, in Andalusia near Cabra, in the province of Cordova, and in the Basque provinces, as is laid down in the Geological Map of France. It probably exists in other localities not yet accurately investigated.

The oolitic formations of Spain have in my opinion some remarkable features. They abound in metalliferous deposits of all kinds, generally scattered in small isolated masses, and seldom in veins. These beds were formerly worked with a profit when mining was carried on on a small scale, and with the help of slaves. Now, however, minerals must be very rich and abundant to enable the companies to make any return. Almost all those who have worked in the jurassic formation have been ruined. *Cuivre gris* or grey copper ore of good quality is found here as well as copper pyrites, both very argentiferous, but soon worked out. Near Barbadillo, at the extremity of the province of Burgos, at the foot of the Sierra de San Lorengo, a bed of this description is now worked, which, both for the

richness and the quantity of the ore, is most promising. The non-argentiferous galena is generally more regular, and a few productive veins of sulphate and oxide of antimony also occur, as, *e. g.* in the neighbourhood of Ateca, in the province of Zaragoza.

In several places the rocks of the oolitic group have been affected by volcanic eruption, by which they have been altered, their colour and structure changed, and all trace of fossil remains obliterated, so that it becomes difficult even for a practised geologist to classify them properly. Thus it is not extraordinary that travellers *en chaise de poste* have fancied that they saw in the centre of Spain variegated marls and red sandstones, trusting only to the external aspect of the rocks seen from the road. I am satisfied that further and more detailed observations will show that the oolitic and liassic formations are more extensively developed than has hitherto been supposed, *i. e.* that they will be discovered over a great portion of the South of the Peninsula.

Other phænomena, which further observations may perhaps tend to generalize, are the thermal springs which rise up in the jurassic formations at or near the point of junction with the more recent formations. We may mention, by way of example, the hot springs of Fitero in the province of Navarra, Arnadillo in the province of Logroño, and Alama near Calatayud. There are also cold sulphureous springs like those of Paracuellos in Aragon, and those of Gravalos in Castille. It must, however, be observed that these same phænomena also occur in the cretaceous formations, although not so frequently; amongst these latter are the "Caldas de Catalogna," and the "Caldas des Asturias," with the geological conditions of which I am not quite acquainted, but I believe them to belong to the cretaceous beds. It is probable that similar cold sulphureous springs existed during the tertiary (pliocene) period; at least it is only by such a supposition that we can explain the origin of the vast deposits of sulphur which are worked at Hellin and Bénamaurel in the province of Albacete, and of that of Libros in the province of Teruel, the argillaceous beds of which are studded with *Planorbis* and *Limnæus* internally filled with native sulphur.

The Cretaceous formation covers the whole southern slope of the great chain of the Pyrenees, extending westwards into the Basque country, to the mountains of Santander, and part of the Asturias. To speak more correctly, this cretaceous zone of the shore of the Cantabrian sea is rather a continuation of that which comes from France along the northern slope of the Pyrenees. The cretaceous zone of the southern slope also extends towards the west through Navarre, a portion of the Basque provinces, the province of Burgos, and the mountains of Léon, so that the great cretaceous deposit of the south of France and the north of Spain is divided in two by the transition and plutonic rocks of the Pyrenees, the jurassic rocks of Biscay, and the Devonian rocks of the Cantabrian mountain-chain. From Figueras in Catalogna to Oviedo in the Asturias is a distance of more than seven geographical degrees.

The Spanish cretaceous zone stretches towards the south with very

little interruption, passing near Burgos, through Old Castille, the provinces of Soria and Guadalajara to Tamajon and Congostrina in the neighbourhood of the celebrated mines of Hiendelencina, which we have already noticed. A ridge which passes by Segovia, the inclined strata of which rest against the granites of the Guadarrama, must be considered as a continuation of the same formation. The cretaceous beds probably exist more extensively in the centre of Spain, and particularly in the ancient kingdoms of Aragon and Valencia. I only know of a few particular spots, as in the province of Teruel, where they overlie the jurassic beds.

The cretaceous formations of central Spain also afford some phænomena which deserve the attention of the geologist. The most remarkable is the elevation of great tracts of country to a considerable height without losing their original horizontality, as the famous plain or plateau of Baraona, celebrated in the annals of Spanish fairies (Brujas or Witches), between Medinaceli and Almazan in Old Castille. It is nearly 5000 feet (1393 mèt.) above the level of the present sea. The plateau or table-land of Algora, province of Guadalajara, on the high road from Madrid to Zaragoza, corresponds to the white chalk (*craie blanche*), and is 4170 feet (1160 mèt.) above the sea. The village of Peñalcazar, in the province of Soria, bordering on that of Zaragoza, is built on a small plateau perfectly horizontal, whilst the neighbouring hills consist of inclined beds of the same formation, and which nevertheless are not so elevated as the plateau itself. At Tamajon, in the province of Guadalajara, on the other hand, the horizontal portion is lower than the inclined beds. The same phænomenon, but on a larger scale, occurs in the valley of the Borunda, province of Navarre.

The great abundance of beds of anthracite (*charbon*) distributed throughout the cretaceous formations of central Spain also deserves notice. In some respects they are not nearly so important as those of true coal (*houille*), but the quality of the fuel is often sufficiently appropriate to be applied to all kinds of industrial purposes. It occurs at Rozas near Reynosa, at a spot not far from Burgos, at several places in the province of Soria, between the town of that name and Moncayo; in the Basque provinces, and perhaps also in the Asturias. The great saliferous deposits are also a peculiarity of our cretaceous formations; the celebrated mine of Cardona in Catalogna may be mentioned, as well as Pozo del Rey in the province of Burgos, the salt springs of Añana, province of Alana, which produce more than 50,000 fanegas of salt*, &c.

The formations of the Tertiary period, both the marine and the lacustrine, overlie all kinds of beds of older date; as, for example, in Catalogna they rest on the chalk, at Valencia on the jurassic, in Andalusia on the transition beds; in the valley of the Guadalquivir, on the various surrounding beds, and even on granite. The actual configuration of the Spanish soil must have been already marked out at the com-

* A *fanega* is equivalent to rather more than 99½ *litres*; and a fanega of salt weighs about 112 Spanish pounds (51 kilog.).

mencement of the tertiary period, with the exception of some partial modifications, for in general all the beds are in a horizontal position, and Col. Silvertop only quotes along the coast of Andalusia some upheaved beds of the eocene period. It must, however, be observed, that along the same shore there are some spots where the marine tertiary formation attains, as at Cuevas de Vera and Sierra Almagrera, an elevation of 900 feet, which gives rise to the question as to whether the waters of the Mediterranean reached that height before the Straits of Gibraltar were broken through, or whether the shore itself has been partially upraised since that period. Amongst the numerous fossils which are found on this coast, there are some species of mollusca of a most extraordinary size; in the vicinity of Cuevas de Vera are also found entombed the remains of elephants, isolated and distributed in particular directions, which were washed down by the streams into the ancient sea, all proving the existence at that period of a more tropical climate than existing at present in this district.

Our tertiary marine formations cover almost without interruption the whole shore of the Mediterranean, and even beyond the Straits in the province of Cadiz; I am not sure whether they extend into Portugal, although it is probable. This tertiary zone extends but a short distance into the interior, except in the valley of the Guadalquivir, where it may be traced without interruption from Cadiz and San Lucar, ascending the river, to Andujar and Liñares, where it rests upon granite, covering up the rich veins of galena which penetrate this plutonic mass of hills. On the northern slope the tertiary beds are but slightly developed. In the interior I know of no marine tertiaries except in the neighbourhood of Burgos towards the north, which must have been a salt lake at that period. In this formation we find a few deposits of lignite, the most important of which is probably that of Utrillas, near Montalvan, in the province of Teruel.

In the third volume of our 'Anales de Minas,' published in 1845, I have given a general account of the great lacustrine formations of central Spain. The most important of all, and that which has been best examined, is what I have called the basin of the Douro (Cuenca del Duero), the surface of which is nearly forty Spanish leagues square, —3400 square kilom. To the west and south it rests on the crystalline or metamorphic formations of Galicia and of the frontiers of Portugal, of the Sierra d'Avila, and of the Guadarrama; to the north on the Devonian beds and on the chalk of the mountains of Léon; and to the east on the cretaceous beds. The lacustrine basin of the Ebro is also very considerable, but I do not know its exact limits. It is, perhaps, somewhat longer, following on both sides the course of the river; but it is not so broad. It rests almost everywhere on chalk, and partly on the jurassic beds. The basins of the Tagus and of the Guadarrama are only separated from each other by ramifications of the mountains of Toledo. The former, which is the most extensive, is placed exactly in the centre of Spain, and includes the capital. The fetid lacustrine limestone of Colmenar serves as well as the granite of the Guadarrama for architectural constructions, and is also used

for statuary purposes, on account of its preserving almost indefinitely its natural whiteness. We also possess other small detached lacustrine deposits in the centre of Spain, as *e. g.* at Libros near Teruel, at Calatayud, where fine specimens of sulphate of magnesia are collected, at Hellin and Bénamaurel, already quoted for the production of sulphur, at Molina d'Aragon with its *Neritina*, nov. sp., and several other localities.

It is well known that the surface of Spain is very mountainous and broken up. The only plain of any extent is that of La Mancha in New Castille, from Tembleque to Santa Cruz de Mudela, a distance of twenty leagues, and elevated more than 2000 feet above the level of the sea. All the other lacustrine plains of the tertiary period have been washed out and furrowed by ante-historic torrents, and by the great rivers which traverse them, which have carried off the greatest portion of their mass, and have moreover cut out the ravines which surround the partial and isolated hills, the horizontal summits of which once formed the bottom of the ancient lake. Other plateaux, on the other hand, are, as we have already pointed out, the bottoms of the cretaceous ocean, which, while being upraised to a considerable elevation, have accidentally preserved their original horizontality. In all the other formations, and even in the cretaceous beds, the strata have generally been tilted in a thousand ways, dipping in every direction, and with every possible degree of inclination, being sometimes quite vertical and even partially reversed. On seeing all these upheavals, all these dislocations, and all the different characters of mountains which have resulted therefrom, it is at once evident that many instances of eruptive rocks must be looked for.

In point of fact our soil has never been at rest, nor is it so even at present. The plutonic eruptions which have pierced the gneissoid rocks have been already pointed out in the western districts; the euphotides, diorites, and black porphyries are more frequent in the central parts of Spain; and the trachytes are almost exclusively confined to the shores of the Mediterranean, and particularly to the southern portion between Marbella and Carthagena. The remarkable and singular deposit of quicksilver of Almaden and Almadenejos must have been occasioned by the action of the euphotides and other analogous volcanic rocks which have burst forth in this district and moulded the mountains or Sierras in such a singular manner. The veins and other metalliferous deposits of Carthagena, Mazarron, and Sierra Almagrera, which yielded such wealth to the Carthaginians under Hannibal, and from which we still derive considerable benefit, are certainly contemporaneous with the basalts of Cabo-de-Gata and of Vera, and the trachytes of Mazarron.

Earthquakes are still often felt at Granada and along the coast of the province of Alicante, where their effects have been very disastrous. Much further in the interior, in the small Sierra del Tremédal or district of Albarracia, in the province of Teruel, eruptions and shocks have been very frequent since the most remote periods; the black porphyry is there seen traversing the altered strata of the oolitic formation. The old inhabitants of the country speak of sinking of the ground

and of the escape of sulphureous gases when they were young; these same phænomena have occurred during four consecutive months of the preceding winter, accompanied by earthquakes, which have caused considerable mischief to the buildings of seven villages situated within a radius of two leagues. They have not, however, been attended with any loss of life, on account of the inhabitants hastening to abandon their dwellings at the first indications of danger.

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4. *On some* Fossil Plants *from the* Lower Lias. By James Buckman, Esq., F.G.S. L.S., Professor of Geology and Botany, Royal Agricultural College.

Towards the base of the limestone beds, forming the lower division of the lias formation in its extension through the counties of Gloucester, Worcester, and Warwick, and probably even contemporaneous with the liassic deposit in these counties, is found a band of limestone of a much purer and harder quality than those with which it is associated.

This band of stone is known amongst the quarrymen by the name of "best paving slab," and is much used throughout the Midland Counties for flooring of barns and farmhouse kitchens; but from its having yielded to the researches of the Rev. P. B. Brodie a beautiful series of insect remains, it is recognized by geologists under the name of "Insect limestone."

The insect remains here referred to have been well figured and described by their discoverer*; and in a *résumé* of the general characters of these, appended by the excellent entomologist Mr. Westwood, will be found the following observation:

"The lias insects resemble forms of ordinary occurrence and of temperate climes, more like North America than Europe†."

Now, as these insects are associated with remains of plants, it cannot be otherwise than interesting to inquire whether the facts as noticed by the entomologist are in accordance with the observations of the botanist, as conclusions supported by the evidence of two distinct sciences must have more weight than when these are conflicting.

The object of this paper, therefore, is to describe the vegetable remains associated with insects in the lower lias, and to distinguish the new forms which have been made out since the publication of the 'History of Fossil Insects.'

The list of the plants from the lower lias, given in the work just referred to, comprehends the following:—

Otopteris obtusa, *Lindl. and Hutt. Foss. Flora*, pl. 128. figs. 1 & 2.
—— acuminata, *Lindl. and Hutt. Foss. Flora*, pl. 132.
Musci.
Confervæ.
Calamites.
Naiadita lanceolata, *Brodie.*

* 'A History of the Fossil Insects in the Secondary Rocks of England,' &c., by the Rev. P. B. Brodie, M.A., F.G.S. &c. 8vo. London, 1845.

† Brodie's Fossil Insects, p. xvi.

But as several acquisitions have been made since the above was published, the following is offered as an amended list, the new species of which will be presently described.

Acotyledonous or Non-flowering Plants.

Natural Orders.	*Genera and Species.*
1. Confervæ. } 2. Musci ? }	Much too imperfect to determine.
3. Equisetaceæ	Equisetum Brodiei, n. sp.
4. Filices	Otopteris obtusa, *Lindl. & Hutt.*
	—— acuminata, *Lindl. & Hutt.*

Monocotyledonous Plants.

5. Naiadaceæ	Naiadita lanceolata, *Brodie.*
	—— obtusa, n. sp.
	—— petiolata, n. sp.

Dicotyledonous Plants.

6. Pinaceæ	Cupressus ? latifolia, n. sp.
7. Haloragеæ	Hippurites ? (new).
8. Umbelliferæ ?	Traces of, too imperfect to determine.
9. Ericaceæ ?	Traces of, too imperfect to determine.

Equisetum Brodiei, Buckman. Fertile frond simple, jointed; each joint inserted in a short sheath, crowned by from eight to ten bluntish teeth. Fig. 1.

Fig. 1.

⅓th of the natural size.

Fig. 2.

Magnified about 6 times.

The portion of the plant from which the above description is drawn up presents four ribbed joints of a frond, the whole being 8 inches long. The British species to which it bears the nearest approach is the *E. palustre*, Linn. The whole frond is entirely simple, that is, without lateral branches: hence it may almost be concluded that the specimen is a remnant of an individual that was in fruit at the time of its entombment; as it is known that barren fronds of these plants have mostly lateral branches more or less developed.

This interesting specimen was obtained from the insect limestone

of Strensham, Worcestershire, and has been named in honour of the intelligent investigator of the insect remains of the bed whence it was obtained.

NAIADACEÆ. Delicate parallel-veined freshwater Endogens, leaves simple, pellucid—much like those of the *Potamogeton* or Pondweed—parallel-veined, without stomata.

Remains of these plants occur in great quantity in a thin band of limestone associated with the Insect bed, which from the prevalence of these vegetables has been named the "Plant bed" by Brodie.

The three forms indicated below are found intermixed and crossing each other in the slabs of stone when split up, and along with them are sometimes innumerable specimens of *Cypris* and *Cyclas*. The species are distinguished by the following characters:—

1. NAIADITA LANCEOLATA, Brodie*. Leaves sessile, lanceolate-acuminate. Fig. 2.
2. NAIADITA OBTUSA, Buckman. Leaves sessile, ovate, somewhat blunt at the apex. Fig. 3 *a*, *b*.
3. NAIADITA PETIOLATA, Buckman. Leaves ovate-lanceolate, on short petioles. Fig. 4.

Fig. 3.

a *b*

Magnified 6 times.

Fig. 4.

Magnified about 6 times.

The specimens from which the figures were taken were obtained from Bristol. These are the most abundant plants in the bed, and are found to a greater or less extent throughout its range. They are from the Rev. P. B. Brodie's cabinet.

CUPRESSUS? LATIFOLIA, Buckman. Leaves closely appressed to the stem, broad at the base, apex bluntly pointed, dorsum elevated so as to give the leaves a sharp triangular outline on a transverse section. Fig. 5.

This no doubt belongs to the Cypress or a near ally. It has much

* Fossil Insects, p. 92 *et seq.* and Murchison's Geology of Cheltenham, 2nd ed. Appendix.

the character of a plant from Lyme, figured in the 'Fossil Flora,' pl. 88; but the leaves are broader and not so pointed. It occurs in

Fig 5.

About twice the natural size.

Fig. 6.

About twice the natural size.

the Insect limestone and the Plant bed, but the specimens are all fragmentary.

Hippurites? These must be considered as only named provisionally. The figures, fig. 6 and 7, represent their forms as made out

Fig. 7.

About twice the natural size.

Fig. 8.

About twice the natural size.

Fig. 9.

⅔ths of the natural size.

by the microscope; from which it will be seen that what are taken to be leaves are exceedingly small and flaccid; the stems and branches, too, are greatly varied.

The drawings have been made from the best of several specimens, but it is more than probable that we shall not be able to make out

their true nature without further search and better-preserved individuals. These are all from the Insect limestone of Strensham, Worcestershire.

Umbelliferæ. Of what I take to be a representative of this tribe, Mr. Brodie has a tolerably perfect seed, fig. 8 *b*, and also a branch of some highly organized plant, which may also belong to the same tribe, fig. 8 *a*. That the little branch belongs to an advanced member of the vegetable kingdom is evident from the plainly-marked articulating surfaces.

Ericaceæ. Leaf net-veined, triangularly concave, without a petiole. Fig. 9 *a*, 9 *b*, Section of the leaf.

This also is only provisionally referred, one leaf only having been found; at the same time it is so undoubtedly Dicotyledonous as to render this small relic an object of interest; and should subsequent examination into the small plants of the lias associated with insects clearly prove the existence of plants of the high Natural Orders to which the two last belong, the fact will be as interesting to the botanist as the geologist.

From these notes upon the vegetation which accompanies the insect remains in the lower lias limestone beds, it will be seen that all the forms of plants belong to families and even species that might have existed in just that kind of climate indicated by the insects; indeed most of them are so emphatically those of temperate regions, that the plants alone would justify us in concluding, either that the beds in which they occur were deposited under similar climatal conditions to those which now prevail in North America; or, that both the plants and insects must have been drifted into the position in which they are found from a great distance.

Mr. Brodie conceives that they were deposited under estuarine conditions, and he appeals to the quantity of insect forms, the shells of *Cypris* and *Cyclas* with which they are associated, and the general absence of insects in other marine strata, as evidence of his views. These conditions, he conceives, would not occur, were organic remains drifted in quantities from great distances. On the other hand, the insects and plants occur in the proximity of *Sauria*, *Ammonites*, *Mollusca*, and *Cidares*, all of undoubted marine origin, consisting too for the most part of species which have been considered as natives of a warmer latitude than the insects and plants would lead us to infer. So that, whether we adopt the estuarine theory or no, the conviction is almost forced upon us, that in this case, where small plants and insects are thus interpolated with larger remains,—if we suppose these latter to indicate a different climate,—the former must have drifted from a great distance to the latter; and indeed the general fragmentary state of both plants and insects greatly strengthens this view.

It may after all be a question whether the great bulk of the animal remains of these lower lias beds necessarily indicate a climate so tropical in character as has generally been supposed; but be this as it may, the plants and insects so nearly indicate the same climate, that

it appears certain they must both have existed under similar circumstances; hence it would appear injudicious to come to conclusions with regard to physical conditions from the examination of a single set of remains.

In the preparation of this paper I have been assisted by the loan of specimens by my friend the Rev. P. B. Brodie, who is heartily thanked for this and other assistance; also by Mr. W. Binfield of Cheltenham, whose cabinet is rich in fossils from the lower lias limestones.

May 22, 1850.

The Hon. George Stephens Gough was elected a Fellow.

The following communications were read:—

1. *On a* Gap *in the* Greywacke Formation *of the* Eastern Lammermuirs *filled by* Old Red Sandstone Conglomerate. By William Stevenson, Esq.

[Communicated by Sir R. I. Murchison, V.P.G.S.]

The occurrence of vast masses of conglomerate on both sides of the Lammermuir chain has been well known to geologists since the days of Hutton and Hall. It appears, however, never to have been suspected that the formations of the north and south sides were connected by a band of considerable breadth running completely across the chain from Doon Hill, about two miles from Dunbar, to the Hardens Hills, about the same distance west from Dunse.

The position, extent, and relations to the adjoining strata of this interesting formation of conglomerate will be best understood by reference to the accompanying sketch (see Map).

The whole district occupied by the greywacke, conglomerate, and trap rocks is almost uniformly hilly, the height of the hills ranging from about 800 to 1400 feet above sea-level, those composed of conglomerate being in general fully as high as those consisting of greywacke or igneous rocks. The tracts occupied by the strata of the old red sandstone and lower carboniferous formations are much lower and flatter, and generally rise no higher than 300 or 400 feet above the level of the sea.

The conglomerate occupies a trough in the greywacke, evidently the result of an ancient dislocation of great extent. At the margins it is seen overlapping the upturned ends of the greywacke strata, which are generally either vertical, or dip at angles of 45° or upwards, to about W.N.W., the dip being rather steeper on the east side of the conglomerate than on the west. The thickness of the mass of conglomerate towards its central parts cannot be readily ascertained, as the deepest ravines do not expose its base. In Shippith Glen it is seen to be several hundred feet thick; but even here there are no symptoms of the underlying greywacke. In regard to composition, it is pretty uniform, consisting chiefly of waterworn masses of greywacke, together with a few of speckled porphyry, and occasionally a

Geological Map of a part of the Eastern Lammermuirs.

1. Luggate.
2. Presmennan Hill.
3. Pitcox.
4. Thurston.
5. St. Denis Chapel.
6. East Aikengall.
7. Shippith Glen.
8. Bransly Hill.
9. Spartleton.
10. Monynut Water.
11. Eye River.
12. Herriot Water.
13. Redstone Rig.
14. Priestlaw.
15. Dye Water.
16. Watch Water.
17. Whin Rig.
18. Windshiel.
19. White Adder Water.
20. Whitchester.
21. Cockburn Law.

Claystone Dykes.
Felspathic Trap.
Augitic Trap.
Old Red Sandstone.
Greywacke.
Conglomerate.
Carboniferous.

a. Vertical. Strike N.E. by E. to N.E. by N.
b. Dip W.N.W. 45°.
c. Dip W.N.W. 45°.
d. Dip W.N.W. 45°.
e. Vertical. Strike N.E. by E.
f. Dip W.N.W. 60° or 70°.
g. Vertical. Strike N.N.E.
h. Vertical. Strike N.N.E.
i. Vertical. Strike N.N.E.

very few pebbles of quartz. The size of these fragments varies from that of peas up to blocks of a ton or more in weight, the general size being that of ordinary sea-shore shingle. These are frequently cemented by carbonate of lime, and in some instances by hæmatitic matter. Where the blocks are largest the cliffs in general readily crumble down, the masses being incoherent from want of a proper mixture of sand. Where the latter is in sufficient quantity, the result is a very hard and tenacious rock. All the materials of which the conglomerate consists appear to have been derived from the adjoining greywacke and porphyritic rocks, chiefly those lying to westward. The dip of the beds is almost invariably nearly E.N.E. at angles varying from 0° to 20° or 30°, and averaging perhaps about 10°. In one or two places, however, in the immediate vicinity of dislocations, the direction and amount of dip are considerably changed.

A remarkable feature connected with this formation of conglomerate is the occurrence therein of numerous veins or dykes of a species of claystone which has been poured from below, in a state of fusion, into fissures, which appear to have been opened during the elevatory process by the subjacent fluid matter struggling to obtain an outlet. This claystone is of a brown or drab colour, hard, and frequently very porous, apparently destitute of augite, but occasionally showing crystals of quartz and hæmatite, together with a little earthy chlorite. In the numerous ravines which intersect the conglomerate I have observed twenty-six of these dykes, and this is probably but a small part of the whole. (See map, in which the positions, and, as far as possible, the directions of some of these claystone dykes are laid down.) They strikingly resemble each other in almost every respect. The great majority are about 3 feet thick, but one or two are under 1 foot; whilst one is 15, and another not less than 33 feet in thickness. They are generally nearly vertical, but undulate a little both vertically and horizontally. Their directions are almost in every instance W.N.W. to E.S.E., or at right angles to that of the trough in which the conglomerate has been deposited. The alteration produced upon the conglomerate adjoining these dykes is very interesting, showing in a very striking manner the intensely-heated state of the molten claystone at the period of its eruption. On each side of the 33-feet dyke the conglomerate has been *fused* to a distance of a few feet, beyond which the half-melted pebbles begin to be distinguishable. The smaller dykes have melted down all the projections of the walls of the fissures which they occupy. The central and deeper-seated portions of these dykes are more compact and crystalline, showing quartz and hæmatitic crystals, whilst towards the surface they become very porous and slaggy.

Fissures other than those occupied by the dykes above described are of frequent occurrence in the conglomerate. In Shippith Glen a great number of minute fissures are seen running in a W.N.W. or N.W. by W. direction. The 'glen' itself is merely a deep ravine with very precipitous sides, and so narrow at bottom that in many places a person cannot force a passage. It is about 200 feet deep, and has obviously originated in a fissure running west by south.

Between East and West Aikengalls is a deep and wide hollow, with a marshy bottom, but without any stream running through it. This runs in a W.N.W. direction, and has evidently had a similar origin.

The conglomerate, both on the East Lothian and Berwickshire sides of the Lammermuirs, is separated from the upper members of the old red sandstone and the lower beds of the carboniferous system by a series of dislocations of great complexity, and many of them of very great extent. These appear all to run in certain determinate directions, or at least as near to such as the nature of the strata with regard to the degree of resistance opposed, would admit. These directions are N.N.E. (or parallel to the strike of the greywacke in this part of the Lammermuirs), W.N.W. (or at right angles to the said strike, being also the direction of the claystone dykes and fissures before mentioned), N.N.W and E.N.E. (these last being *intermediate* to the former directions).

Of these dislocations the most remarkable is that which extends from a point near the Knock Hill (about two miles from Dunse) in a direction nearly S.S.W., passing along the east side of the conglomerate hills of Hardens, and proceeding by way of Choicelee, Marchmont, &c., crossing the Tweed near the mouth of the Teviot, and traversing Roxburghshire by way of Hunthill, Southdean, the upper part of the Jedwater, the east side of Lariston Fells, &c. The strata all along this line of fault are thrown down on the east side. The amount of displacement along the east side of the Hardens is probably at least 500 or 600 feet. Near Choicelee the old red sandstone strata adjoining the line of fault are *retroflexed* for some distance. A very interesting circumstance may here be mentioned. This is the occurrence in Roxburghshire of a gap in the greywacke precisely similar to that which forms the subject of the present notice. This gap is filled up by strata of the old red sandstone and lower carboniferous formations, and runs parallel with the line of dislocation referred to. Its situation is also exactly the same with regard to the dislocation as the Lammermuir gap, both occurring about three miles to the westward of the course of the fault*. The width of the two gaps is also very nearly the same. In fact that part of the county of Roxburgh which lies to westward of this line of fault is almost the counterpart, in its geological features, of the corresponding portion of Berwickshire. The Hawick trap dyke intersects this line of fault near Fallside, in Chesters parish.

Besides this, there are several other dislocations connected with the conglomerate. One runs E.S.E. from Elmford for a few miles, throwing down the strata on the south side. Another proceeds S.S.E. from Elmford to the east side of the Knock Hill, where it meets the great dislocation first described. It throws down on the east side to the extent, in some parts, of probably 800 feet. On the Lothian side of the Lammermuirs, in the prolongation of this line, is a similar dislocation, which passes near Halls, and also throws down on the east side. A fault running nearly at right angles to this (E.N.E.)

* See map attached to Mr. Milne's paper on the Geology of Roxburghshire.

passes by way of the village of Spot and the north side of Doon Hill, throwing down the old red sandstone strata to north. On the east side of Doon Hill another N.N.W. slip cuts off the conglomerate from the newer strata, which it throws down to east. The amount of displacement here must be many hundred feet. Connected in all probability with the two last-mentioned faults is the great dislocation, which may be seen on the line of the North British Railway, in a cutting near Broxburn (about two miles from Dunbar). The strata are here seen to be vertical for a considerable distance with a N.N.E. strike. From the sea-shore at Thornton Loch a line of fissure appears to run in a westerly direction by way of Innerwick, Thurston, &c., and across the conglomerate to Barnhead. The aspect of the country near this line is remarkably broken and irregular. In the course of the rivulet between Braidwood and Thornton, and in that which runs past Branxton at a point about 400 yards above that place, sections are exposed which show a great dislocation running apparently N.N.E. to S.S.W. At these places the lower carboniferous strata come close up to the conglomerate, and are much crushed and tilted at high angles. At one place they are seen to be retroflexed to a distance of about 100 yards from the slip.

The above are only some of the chief dislocations which have affected this disturbed district. To investigate the whole would be a work of very great labour and difficulty, though certainly of great interest. In an investigation of this kind, however, the want of exact maps, furnishing an accurate and trustworthy topographical basis for a survey, is felt to be an insuperable barrier. This obstacle will no doubt be removed in due time by the publication of the maps of the Ordnance Survey.

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2. *On the* Stratified Formations *of the* Venetian Alps.

By Count Achille de Zigno, F.G.S.

The region to which the present memoir refers contains localities which at all times have attracted the attention of naturalists. The labours of Arduini, Fortis, Da Rio, Marzari, Brongniart, Catullo, Pagini, Brocchi, Trettenero, have pointed out its more remarkable features; and some of the Members of this Society have cast a rapid glance on the more interesting phænomena. Feeling convinced that this portion of our mountains would furnish the clue to the geology of Northern Italy, I have prosecuted my researches for several years, with the object of bringing the stratified formations of the Venetian Alps into co-ordination with the classic deposits of Europe. I have at length succeeded in recognising and establishing certain geological horizons, in rectifying some of the earlier observations, and in satisfying myself of the correctness of others subsequently made. I have had occasion to avail myself of stratigraphical and palæontological reasoning, according to the localities; and I indulge the hope that the result of my studies will be a more rational explanation of the structure of our mountains.

The district which I am about to describe is bounded on the east by the Tagliamente, on the north by Carinthia and the Tyrol, on the west by the Adige, and on the south by the plain which extends to the Po.

The Tagliamente, after running from west to east along the valley called the 'Canal di Sochieve,' which is parallel to the main chain of the Alps, receiving the torrents which run from north to south (such as the Lumici, the Degau, the Bret, and the Fella), turns sharply to the south and enters the plain between S. Daniele and Spilimbergo, after having intersected jurassic, cretaceous, and tertiary formations; whilst the torrents I have mentioned cut through still older strata, which I make no question are triassic. The celebrated Von Buch in 1824 pointed out that the Tagliamente from its source to its junction with the Fella formed the limit between the limestone mountains to the south and the formations to the north, which he then called grauwacke. It is easy to verify the truth of this observation of M. von Buch's, for as the valley called the Canal di Sochieve runs parallel to the principal chain, the calcareous beds are seen to dip from north-west to south-east, whilst the older rocks are exposed in the transverse valleys which conduct the torrents from the main chain to the left bank of the Tagliamente. In these valleys, micaceous grits, argillaceous schists, and a thick formation of sandstones, accompanied by gypsum and by magnesian and bituminous limestones, indicate the presence of older rocks. Beds of coal have also been found here, and it appears certain that the coal is intercalated between the magnesian limestones. Prof. Meneghini, the distinguished botanist, has not satisfied himself whether this formation belongs to the trias or to the zechstein; but from the fossils which I have found in it, I am of opinion that it is triassic. These consist of *Aviculæ*, among which is the *A. socialis*, Schlot. sp., with *Terebratula vulgaris*, Schlot. sp., and other shells, not determinable, but with triassic characters. The thick beds of limestone which underlie the grits do not contain these fossils, which makes me suspect that these latter may be older than the muschelkalk. This question I propose to discuss in a work devoted to the geology of Friuli, which is still a virgin soil. Be this as it may, the grits which cover the limestones are certainly of triassic age. In Dechen's Map, published in 1839, a considerable formation of micaceous schist is marked to the north of the Tagliamente, between the sources of the Piave and the Degau, and to the east of the latter torrent a disconnected mass of argillaceous schist is represented as extending between the jurassic rocks of Friuli and the Pœcilian formation of the Carniola Alps. I have no doubt that when I shall have extended my researches to that quarter, I shall find the older rocks of the chain; but on the side of Paluzzo, Rigolato, Sapada, to the very sources of the Piave, the higher mountains consist solely of thick beds of the jurassic age. This rock forms all the heights bordering the valleys through which flow the torrents Argino, Meduna, and Zelline, as well as the summits of the high mountains of Friuli, whose bases, as we have seen, to the north are triassic. To the south, and in certain basins, the higher country is composed of neocomian and cretaceous

beds, whilst the tertiary formations exhibit themselves in hills which flank the Tagliamente, where it issues from the high Alps, and especially to the east of its left bank beyond Venzone and Gemona, to the south of which, between S. Daniele and Trigesimo, the fertile hills and green pastures are formed by still newer beds of sands and pebbles, whose lower strata are connected with the tertiaries, whilst the upper present the characters of a diluvium. In the northern parts of Friuli the trias continues to show itself beneath the jurassic beds uninterruptedly to the valleys from which the Piave takes its rise; but in this part of our mountains the lower arenaceous beds acquire a great thickness, and repose upon mica slate, which more or less visibly forms the base of all the high mountains of the Lombardo-Venetian territory, and which is particularly well exhibited in the northern flank of this great outer barrier to the Alps of the Tyrol and Carinthia. The mica slate and triassic grits are also seen in the valleys which run south parallel to the Piave, from whence it can be followed in the Cadore.

These formations are seen largely developed in the mountains between the valley of Sexten and that of La Boite, in some parts of which the trias is covered by argillaceous schists and a greyish limestone, which I suspect from its position may be lias, but in which as yet no fossils have been found. Descending the valley of La Boite and turning to the south, the older beds have disappeared under the jurassic rocks, which compose the mountains the whole way to the Belluno basin, whilst the valleys of Zoldo and Cordevole, which open on the right bank of the Piave, enable us again to see the oldest fossiliferous formation re-appearing in a line parallel to that where it shows itself in the valley of La Boite. Its limits may be traced in the districts of Agordo, and of Primiero, to Valsugana and the basin of Trent, in a line running north-east and south-west, which is at a right angle to the general dip of the beds. All the mountain masses north of this line exhibit the older rocks, frequently disturbed and upset by the granites and porphyries which branch from those of the Tyrol, and by melaphyre. To the south of this line, like a great barrier to the older rocks, rises the mass of oolitic, neocomian, cretaceous, eocene, miocene, and pliocene formations in conformable stratification.

Thus far my observations tend to confirm what Sir R. I. Murchison announced in 1829, that is to say, the conformability of the jurassic, cretaceous, and tertiary formations. This may be seen even in the parts most disturbed by eruptive rocks, and may be traced down to the lowest, for the parallelism of the beds from the mica slate to the jurassic may be seen in the district of Recoaro, which is, so to say, a triassic island upheaved by greenstone eruptions, to the south of the line I have indicated, and in the middle of the oolitic rocks of the Vicentin.

The observations I have made in the neighbourhood of Belluno, which are partly confirmatory of those of M. Catullo, enable me to fix the southern limit of the mica slate and trias from the basin of Trent along the Brenta into Valsugana, then across the Canal di S. Bovo, the valleys of the Cismon, the Mis, the Cordevole, the

Maé, the Boite, to the upper part of the Cadore, whence it turns to the east and follows the left bank of the Tagliamente. It is true that the tops of the mountains beyond this line are sometimes of jurassic age, but the bottoms of the valleys always display the more ancient rocks, which extend from hence, forming the principal part of the mountains bordering the valleys of the Fiemme and the Fassa; so that in these two valleys, as well as in the transverse ones of Travignolo, S. Pellegrino, Livinal-lungo, and the well-known locality S. Cassiano, the trias appears everywhere well-developed and marked by its most characteristic fossils. The line I have just traced, which is established by very careful observations of my own, as well as by those which are scattered through the writings of MM. Pasini, Fuchs, and Catullo, obliges us to throw into the division of older rocks much which is classed as jurassic in the Maps of MM. von Dechen and Morlot. The deep valleys in the neighbourhood of Belluno give opportunities of studying these rocks and observing their perfect conformability. In fact the jurassic masses, which form the crests of the high mountains of the Tyrol, the Bellunais, Cadore, and Friuli, descend to the bottom of the valleys of the Piave and the Brenta, where they are covered by the cretaceous and tertiary hills which gradually subside into the plains north of Venice. They can be studied in the valleys of the Brenta from Bassano to Borgo di Valsugana; of the Piave from Belluno to Perarolo; the valley of Pantena in the Veronais; the road from Vallarsa to Roveredo, and thence to Trent; and the valley of the Astico in the Sette Comuni, as well as in the transverse valleys which intersect this great calcareous plateau. But before speaking of the jurassic rocks, properly so called, I must call attention to beds which are apparently older than the oolitic and younger than the trias. Above the beds of the latter, brown or greenish clay-slates, associated with a bluish grey limestone with spathose veins, are found in several parts of our Alps, apparently older than the oolites and belonging possibly to the lias. They occur in Cadore, in the Bellunais, and in the Tyrol, and as they contain no fossils, their place in the chronological series must be doubtful. They are not found in the great valleys of the Piave, the Brenta, the Astico, the Agno, and the Adige; and in their place we find, beneath the undoubted oolite, alternating beds of compact and crystalline limestone, apparently due to some alteration of the strata which were deposited between the Keuper and the lower oolite or système Bathonien of M. d'Orbigny. The crystalline structure proves that these beds have undergone plutonic changes; nevertheless wherever these beds are seen reposing upon the trias, the latter shows no trace of metamorphism; and I may state generally, that all the sedimentary beds in these mountains, from the mica slate upwards to these crystalline limestones, prove in the clearest manner that they have undergone no alteration whatever from plutonic agency, always excepting those partial changes in the immediate vicinity of igneous rocks which are confined to particular localities and do not influence the general aspect of the formation. I can only explain this metamorphism and the absence of fossils by attributing it to an elevation of temperature and an evolution of gaseous

substances, which altered the sediments then forming in the sea. The cause must have been one which acted in a horizontal direction, and not in a vertical one, as is usually the case in true plutonic action. I conceive that cracks or vents may have opened at points distant from each other, up which have escaped great volumes of gas accompanied by great heat, which was communicated to the triassic sea, enabling it to alter chemically the deposits then forming, and favour their crystallization even at points very distant from the orifices. The occurrence of compact limestones alternating with the crystalline appears to be opposed to this hypothesis; but it is easy to suppose that the gaseous emanations took place repeatedly, after intervals of repose, during which the sea tended to recover its temperature, analogous to the periods of repose of modern igneous and mud volcanos.

This theory appears to me to account for the want of metamorphism in the inferior beds, the alternations of crystalline and compact limestones, and the passage from the compact to the oolitic structure which is seen gradually to develope itself in the jurassic rocks. The oolitic structure, so common in volcanic regions and in the neighbourhood of thermal springs, according to my views is also due to thermal causes, and has a direct relation to their intensity. The alternations of oolitic with compact beds indicate the periods of activity or repose, and the gradual change observable in the higher beds points to a gradual cooling-down of the temperature of our seas to the present time. The crystalline limestones which appear to form the lower limit of the jurassic rocks are covered by others of oolitic structure, which alternate with a grey compact limestone and with conglomerates of limestone fragments. Fossils are rare in the crystalline as well as in the oolitic limestone; they only begin to be common in a grey, yellowish, or reddish limestone, intercalated among the oolites, which contains casts of *Trochi* and *Melaniæ*, closely resembling species which in England, France, and Germany are characteristic of the lower oolite. The same limestone contains a new species of *Perna*, resembling the *Gervillia Benauxiana*, D'Orb. Above these are found grey shelly beds, together with one containing the well-known *Phytolites* of Rotzo in the Sette Comuni. No one, as far as I am aware, has studied these vegetable impressions, which I propose to describe and figure in my work on the Alps: in the meantime I may state my opinion that this bed also is lower oolite. Marl, alternating with ash-coloured beds, containing *Terebratula ornithocephala*, Sow., *T. bullata*, Sow., an *Astarte*, a *Nerinæa*, and fossils in bad preservation, announce the commencement of the middle oolite. Here begins a white, yellow, and red Lumachello marble, in which I have found no fossils except traces of an *Astarte*: it resembles the marble of Arzo in Lombardy, where it contains *Terebratula ornithocephala*. Above this Lumachello, which is very persistent through our mountains, occurs the red, white, or grey limestone, which goes by the name of Ammonite limestone (calcaire ammonitifère), from the enormous number of Ammonites which swarm in its beds. In the basin of Trent, in the mountains forming the valley of the Adige, in the basin of Roveredo, in the high mountains of the Veronais, in

all the vast calcareous region of the Sette Comuni and that which extends from the left bank of the Brenta to Belluno and Friuli, this well-marked horizon may be traced. Even in the group of Euganean Hills, which rise like an island in the plain at a distance of thirty miles from the chain, in the midst of the confusion produced by the trachytes and basalts, I have recognized the jurassic formation by the presence of this ammonite limestone abounding in fossils. These prove its synchronism with the Oxford clay and coral rag of England, and cannot be confounded with those of the other red limestones of Italy which have been referred to the lias.

The following are very abundant:—

Ammonites anceps, *Ziet.*
—— athleta, *Phill.*
—— viator, *D'Orb.*
—— Hommairei, *D'Orb.*
—— Zignodianus, *D'Orb.*
Ammonites Tatricus, *Pusch.*
Cidaris coronata, *Goldf.*
Glypticus hieroglyphicus, *Agass.*
Ananchytes bicordata, *Lamk.*

And in the upper beds, *Ammonites perarmatus*, Sow., and *A. biplex*, Sow., several *Aptychi* of the family *Lamellosi*, and lastly *Terebratula diphya*, Buch, and a *Terebratula* allied to *T. triangularis*, Nilss.

Hence it would appear that the upper beds of the ammonite limestone which are the most argillaceous represent the upper jurassic. Above the ammonite limestone and conformable to it, as may be seen both on the plateau and on the southern flank of the chain, appear the different groups of the cretaceous system.

Hitherto Italian geologists had included all its strata under the name of Scaglia, which they conceived to represent the upper cretaceous beds, while some of them looked on the ammonite limestone as the representative of the lower greensand. M. von Buch, at the meeting of Italian naturalists at Milan in 1844, showed that the ammonite limestone belonged to the oolites; and the fossils I have since discovered in it enable me to place it in the Oxfordian group. In like manner by fossils I have been enabled to distinguish incontestably the different cretaceous beds which lie upon it, the lowest of which is a white or sometimes greyish limestone with a conchoidal fracture, which we call Biancone. Its perfect conformability with the upper beds of the ammonite limestone on which it is seen to repose, had caused geologists unacquainted with its fossils to classify it with the upper oolites; while others, founding their conclusions on mineralogical characters, confounded it with certain beds of the scaglia, which though thinner strongly resemble the biancone, and can only be distinguished from it by fossils.

It was in the biancone of Mont Vignola among the Euganean Hills that I first found specimens of *Crioceras*, and especially the *Crioceras Emmerici*, Lév., which is characteristic of the lower Neocomian beds. This made me suspect that this rock was our representative of the Neocomian system, and I lost no time in satisfying myself of this by studying the biancone fossils collected by myself, as well as those of the museums of M. da Rio, of M. Parolini, and of the University and the Seminary of Padua. After careful researches I have procured from the biancone of the Euganean Hills, in the neighbourhood of

Padua, from that covering the oolitic plateau of the Sette Comuni, and from that which forms the base of the subalpine hills of the Vicentin and extends to Friuli, the following fossils, which are highly characteristic of the Neocomian formation :—

Belemnites latus, *Blainv.*
—— dilatatus, *Blainv.*
Ammonites incertus, *D'Orb.*
—— difficilis, *D'Orb.*
—— quadrisulcatus, *D'Orb.*
—— Grasianus, *D'Orb.*
—— Morelianus, *D'Orb.*
—— cryptoceras, *D'Orb.*
—— subfimbriatus, *D'Orb.*
—— rectirostratus, *D'Orb.*
—— Juilleti, *D'Orb.*
Ammonites Astiarianus, *D'Orb.*
—— inæqualicostatus, *D'Orb.*
—— infundibulum, *D'Orb.*
Crioceras Villiersianum, *Leym.*
—— Duvalii, *Lév.*
—— Emerici, *Lév.*
Ancyloceras pulcherrimum, *D'Orb.*
—— Puzosianum, *D'Orb.*
Aptychus Didayi, *Coqd.*
—— radians, *Coqd.*

In the upper beds I even found the *Hippurites neocomiensis*, D'Orb., which seems to indicate the upper Neocomian, or 'terrain Aptien.' My observations, therefore, prove that the two Neocomian groups are found in the Venetian Alps and are represented by our biancone. Palæontology has also enabled me to discover traces of a formation which Italian geologists have never yet recognized in our Alps; I mean the gault, or 'terrain Albien' of M. d'Orbigny. Indications of this group are afforded by certain *Cephalopoda* found in a whitish argillaceous limestone, lying on Neocomian beds in the plateaux of the mountains of the Sette Comuni. These consist of traces of a *Hamites*, which I found near Galio, and which may probably be the *H. Bouchardianus*, D'Orb., collected by MM. d'Orbigny and Bouchard de Chantereaux from the clays of the gault at Wissant; a young specimen of *Ammonites Velledi*, Michelin, brought to me from the environs of Canove; another Ammonite which is unquestionably the *A. Royssianus*, D'Orb., from the valley of Frenzena; and lastly, the *A. nodocostatus*, D'Orb., originally found in the gault of Escargnolle in the Var by M. Astier, and which was found here near Galio. Few as these fossils are, they authorize us to pronounce that the argillaceous limestone beds above the biancone in the Sette Comuni contain gault remains, and are to be classed with that group. The beds might easily be confounded with those above and below, for in mineralogical characters they are not distinguishable. Organic remains alone determine this horizon.

Between the beds just described and the scaglia, which I refer to the chalk, or 'terrain Sénonien,' occurs a limestone mass of variable thickness, consisting of beds of very hard conglomerated rock, both the pebbles and matrix of which are calcareous; it contains also little fragments of a sparry structure, which may be broken shell, and which give the rock in some parts a crystalline aspect. This rock is most developed in the neighbourhood of Belluno. MM. Catullo and Pasini have noticed it in the mountains which surround the lake of S. Croce and form the heights of Alpago. The former gentleman refers it to the Neocomian period, and the latter gives it a still greater antiquity. For my own part I place it in the upper greensand, or 'terrain Turonien,' both from its geognostic position and from its organic remains.

For besides the many new species described by M. Catullo, we find several well known as characteristic of the 'craie chloritée.'

The new species of M. Catullo are as follow:—

Nerinæa Borsoni, *Bronn.*
Hippurites nanus, *Cat.*
—— contortus, *Cat.*
—— maximus, *Cat.*
—— fasciatus, *Cat.*
—— rugulosus, *Cat.*
—— Fortisii, *Cat.*
—— Turricula, *Cat.*
—— dilatatus, *Cat.*
Hippurites imbricatus, *Cat.*
—— Zoveti, *Cat.*
Sphærulites duplovalvata, *Cat.*
—— umbellata, *Cat.*
—— Da Rio, *Cat.*
—— Gazola, *Kefst.*
Baculites Alpaghina, *Cat.*
—— flexuosa, *Cat.*

Those which determine me to classify this bed with the upper greensand, or 'terrain Turonien' of M. d'Orbigny, are the following:—

Acteonella lævis, *Sow.* sp.
—— gigantea, *Sow.* sp.
Actæon ovum, *Duj.* sp.
Hippurites cornu-pastoris, *Desmoul.*
—— organisans, *Desmoul.*
Radiolites Ponsianus, *D'Archiac*, sp.

It appears to me impossible, on palæontological grounds, to admit of any classification of this deposit different from that which I propose, and which confirms what M. d'Orbigny long ago advanced, viz. that the *Rudistes* of Italy were confined to his third zone. Previous to my discovery of the true Neocomian beds, the *Rudistes* of this part of Italy had been considered of Neocomian age; but they have been placed even below the ammonite limestone which abounds in jurassic fossils. When, however, M. von Buch at the meeting at Milan established the true place of the ammonite limestone among the oolites, these hippurite beds of Santa Croce were confounded with the scaglia, which scaglia palæontological reasons force me to consider as upper cretaceous, or 'terrain Sénonien.'

The upper cretaceous group of this country consists either of a brick-red, sandy limestone, or of a red, white, or grey argillaceous limestone, called by Italian geologists Scaglia. It is characterized by true chalk fossils, such as *Ananchytes ovata*, Lamk., *A. tuberculata*, Defr., *Holaster natica*, *Inoceramus Cuvieri*, Sow., *I. Lamarckii*, Park. The beds vary in thickness, but are usually thin, fragile, and almost schistose, from whence its name of Scaglia. They pass downwards into grey beds with dark spots, occasioned by fucoids. Sometimes a black bituminous limestone occurs subordinate to the formation.

This is the group which everywhere in these Alps forms the base of the cretaceous system. Without the help of fossils it would have been difficult to have traced these limits on account of the general conformability of the strata from the lowest beds of the trias to the most recent, which obliges us to admit of a vast period of tranquillity in this portion of Europe. It is true that during their deposition eruptions have taken place which have fractured them and occasioned the formation of conglomerates; but these eruptions have been very partial, and are nowise connected with the great upheaval, which has been occasioned by the igneous rocks of the Tyrol. The partial eruptions of melaphyre, dolerite, basalt, trachyte, &c., have caused

the protrusion of the mica slate and trias in the basin of Trent and near Recoaro, the upheaval of the Euganean Hills, and of the great tertiary deposit of the Vicentin. The basaltic eruptions took place towards the end of the secondary and during the commencement of the tertiary period. They have been so well described by M. Bronguiart in his work on the calcareo-trappean rocks of the Vicentin, that I shall only make one remark, which is this,—that the basaltic conglomerates in many spots have covered the upper chalk, and mixed themselves with the tertiary limestone then forming, so as to make it difficult to separate the two formations; whilst in other places the basalt is so trifling in quantity as to have formed with the eocene sediment a calcareous grit. For instance, in the Euganean Hills, this grit, containing *Operculina complanata*, Bast. sp., beds of *Nummulites*, crinoidal stems, and the *Pentacrinites didactylus*, D'Orb., reposes on chalk containing *Ananchytes tuberculatus*, Defr., and *Inoceramus Lamarckii*, Park. In the Berici Hills these grits pass into a 'calcaire grossier,' containing *Cerithium giganteum*, Lamk.: at Montecchio Maggiore, at Ronca, and at Bolca in the Veronais, the conglomerate and limestone contain an enormous quantity of decidedly eocene fossils, which are again met with at Castel Gomberto in the Val di Lonte, and at the base of the whole zone of tertiary hills from Verona to Friuli; for they have been noticed near Bassano, in the hills of the Asolano, and the hills beyond the Piave. One very interesting locality is at the village of Galio in the Sette Comuni, where at an elevation of nearly 3000 feet a limestone with *Cerithium giganteum* is seen to repose conformably on upper cretaceous beds. This junction is also visible near Bassano, along the escarpments of the valley of the Brenta, as pointed out by Sir R. I. Murchison in 1829: all my observations since have but confirmed the ideas of that distinguished geologist, as I have acknowledged in a pamphlet and in a note inserted in the Bulletin of the French Geological Society*.

Another good junction of these formations is at the crest of the hills separating the valleys of the Agno and the Schio. Descending from these hills towards Magré across conglomerates and nummulitic beds we come upon a brick-red limestone resembling the scaglia, but containing small *Nummulites*, which by degrees disappear, and in their place we find *Ananchytes* and *Inocerami* proper to the chalk. Turning to the south to the hills of San Malo, and descending to Ennichilina, we come upon a bed full of *Nummulites* of various sizes, from a breadth of three to forty-five millimetres (·118 to 1·77 inch) and a thickness of two to eight millimetres (·078 to ·314 of an inch). As usual the smaller are the thickest, for the larger are scarcely two millimetres in thickness. MM. de Verneuil and d'Archiac, to whom I sent them, think they can distinguish amongst them the globular variety of *Nummulites Biaritzana*, D'Archiac, and refer the largest to *N. polygyratus*, Desh., and *N. distans*, Desh., of the Crimea.

* See observations on the jurassic, cretaceous, and nummulitic rocks of the Venetian Alps, in the memoir on the Alps, Apennines, and Carpathians, by Sir R. I. Murchison, Quart. Journ. Geol. Soc. vol. v. pp. 179, 218 *et seq.*, and Sections, pp. 218, 219, &c.

These beds also contain *Trochus cumulans*, Brongn., two species of *Bulla*, one of them closely allied to *B. lignaria*, Linn., *Terebellum obvolutum*, Brongn., small *Cyprææ*, casts of *Cerithium*, *Natica*, *Conus*, *Mactra*, &c., and the beautiful *Nautilus* which characterizes the nummulitic beds of the Vicentin. Mixed with the Nummulites I have found joints of the *Apiocrinites ellipticus*, Miller. From this it would appear that this cretaceous fossil lived down to the tertiary period, unless indeed this bed be composed of regenerated materials of the upper chalk during the basaltic eruptions which took place at the close of the cretaceous period, a question which the locality does not admit of our solving. I am however of opinion that the progress of palæontology will enable us to establish beds of passage in those formations which lie conformably on each other. Observations directed to this object will perhaps prove that the 'terrain Etrurien' of my late friend M. Pilla is composed (as I formerly advanced) of the lower tertiary and upper cretaceous.

East of the Brenta, trap and breccias do not occur intermingled with the lower tertiaries. These consist of ash-coloured marls full of eocene fossils, alternating with limestones containing *Nummulites*, *Miliolites*, and fossils of the calcaire grossier of Paris. These beds, which furnish a good building-stone, are covered by clays, sands, and molasse containing species of *Pecten* and *Scutella* of miocene age, which again are covered by lignite and pebbly beds in which I have found *Ostrea Virginiana*, Gmel., and *O. longirostris*, Lamk. The low hills in the neighbourhood of Schio are also of molasse, containing *Spatangus Hoffmanni*, Goldf., and *Pecten opercularis*, Lamk. Here the eocene is hidden, and does not appear again till we come to S. Georges de Polio, where an inversion of the beds has taken place, so that the eocene nummulitic beds are seen overlaid by the upper cretaceous, and these by still older cretaceous strata, the whole intermingled with basaltic tuff. This section had caused naturalists to believe that there are nummulites below the chalk, an error which M. Pasini was the first to rectify.

In all the Trevisan hills the miocene beds pass gradually into conglomerates and sands, cemented by calcareous matter, of a more recent age; these form the southern slope of all the hills to Friuli. It was probably this formation which furnished the tooth of *Mastodon angustidens*, quoted by Cuvier, which was found near Soligo. I have never succeeded in finding any fossils in it, though I have searched it diligently, and particularly the caverns in the hill called Bocco del Montello. There is, however, a small cavern hollowed out of the nummulitic beds and filled with clay at the base of the hill of S. Lorenzo, between Montebello and Verona, which contains an abundance of bones. Dr. Scortegagna, who procured some of them, has recognized the teeth and bones of *Hippopotamus* and *Rhinoceros*. Professor Catullo subsequently published an account of the bones found in the caverns of the Veronais and of the Venetian provinces. He refers them to *Elephas primigenius*, Blumenb., *Equus adamiticus*, Schlot., *Ursus spelæus*, Rosenm., *Cervus megaceros*, Hart, *Canis vulpes*, Linn., *Sus priscus*, Goldf. Stags' horns have been found in the clays of our

plains, and the peat bogs at the foot of the Euganean Hills contain the teeth of the horse, the boar, and a small animal allied to the beaver.

This rapid sketch of our stratified rocks in the north of Italy is intended to show how by the aid of fossils a suite of formations from the mica slate to the most recent can be traced; beds often geographically distant can be shown to be identical; and some which are identical in mineral composition can be proved to be distinct.

With the aid of fossils I have marked the boundary of the trias, and shown that in our jurassic formation the lower and middle divisions occur with traces of the upper. Next I have shown that our lower cretaceous beds are divisible into 'Neocomian' and 'Albian,' and the upper into M. d'Orbigny's two divisions, 'Turonian' and 'Senonian.' Our tertiaries, not having previously been accurately studied, had all been confounded in one group, the Miocene. I have shown that they are distinguishable into Eocene, Miocene, and Pliocene, and have satisfied myself that our great nummulitic formation is undoubtedly Eocene. I doubt whether there are any secondary nummulites. In a memoir on the cretaceous beds of Italy, I mentioned the occurrence of traces of nummulites under the scaglia; but I have since satisfied myself that these lenticular bodies were broken shells rounded by attrition. In the Alps I look upon nummulites as the most characteristic fossil of the tertiary period, and I shall regard as tertiary any beds wherein they shall be found to occur.

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3. *On the* Age *and* Position *of the* Limestone *of* Nash, *near* Presteign, South Wales. By James Edward Davis, Esq., F.G.S.

The picturesque and very valuable mass of limestone, situated on the borders of Wales, near the road leading from Presteign to New Radnor, and overhanging the hamlet of Nash, is probably known by name to most Silurian geologists, but I am not aware that it has been carefully examined by any geological investigator since the publication of Sir Roderick Murchison's 'Silurian System.' The interesting features of the neighbourhood of Presteign and Old Radnor could not fail to attract the attention of that distinguished geologist, who says of the Nash beds that there is not perhaps in Great Britain a finer mass of altered and crystalline limestone.

After an examination of this district, the details of which are given in the 'Silurian System,' Sir Roderick Murchison states this limestone to be identical in position and organic remains with that of Wenlock.

In conformity with this opinion, and, indeed, following it, the views of the structure of the surrounding district were framed and shaped, as far as I am aware, by all who had any definite idea on the subject, or took an interest in its investigation, but more particularly by the Rev. T. T. Lewis of Aymestry, and myself.

The first surmise I heard that this limestone is referable to a lower bed, was from Professor Sedgwick, who in the summer of 1846 took a rapid glance at the district. Finding the limestone resting on beds of undoubted Caradoc sandstone, and not at the time being aware or recollecting that any other opinion was entertained, he inferred that the formation was identical with that of Woolhope. More recently, the officers of the Geological Survey of Great Britain have given unmistakeable indications of a similar opinion*.

The true character of this limestone becomes a question of considerable interest, as upon the accurate definition of the beds in *Siluria proper* must in a great measure depend the correct knowledge of their prototypes in other regions.

To elucidate this question it is necessary to state, very briefly, the geographical position and relation of the limestone to the adjacent country.

The sandstone beds above-mentioned occupy the summit ridge and greater part of a hill south-west of Presteign called Cam or Caen Wood, which rising to the height of about 1000 feet from the sea-level, forms the northern boundary of the valley of Knill. The strike of these beds of sandstone and grit (N.E.) is nearly identical with that of the more extensively developed Caradoc sandstone in Shropshire and Caermarthenshire, and with which they form an intermediate link, separated however by overlying deposits in both directions. Between Caen Wood and the south-west point of the Shropshire Caradoc beds, a distance of about twenty miles, the only observed connection is a slight upcast of grits in the Park of Brampton Brian†.

The strata of sand and grit of Caen Wood form an anticlinal line dipping N.N.W. on the north or Presteign side, at an angle of 50°, and S.S.E. on the south flank of the hill, at a similar angle. The northern dip is seen above the old and now abandoned excavations of limestone at the 'Sandbanks,' half a mile south of Presteign Gaol. The southern or reverse dip is seen on the side of the turnpike-road leading from Corton towards Nash, and in various parts of the wood overhanging the same road. At the quarry near Corton turnpike-gate the bedding is indistinct, and Sir Roderick Murchison observes, that the rock, which is here a conglomerate, strongly resembles a volcanic grit; and there can be no doubt that he is correct in assuming the elevation of these beds to be due to the eruptive action at Old Radnor, a few miles to the south-west, the force of which prolonged to the north-east has resulted in the anticlinal line of the Ludlow Promontory and the valleys of elevation of Kinsham and Wigmore.

The great bulk of the Nash limestone lies on the south side of the

* See abstract of paper by Messrs. Ramsay and Aveline on the Structure of parts of North and South Wales, Quart. Journ. Geol. Soc. vol. iv. p. 294.

† This is mentioned in the paper already cited by Messrs. Ramsay and Aveline. It was I believe first discovered in the autumn of 1838 by the Rev. T. T. Lewis, who communicated the fact to Sir R. Murchison at that time, previous to the publication of the 'Silurian System,' but too late for its insertion on the map.

sandstone ridge, and is locally known as 'Nash Scar.' It is a pure and highly crystalline limestone, rising about 300 feet above the turnpike-road which runs at its base. It is extensively quarried and burned, and must be at least 100 feet thick. The absence, however, of any decided traces of stratification where it is most largely developed, renders it difficult to speak with accuracy on this point. It undoubtedly, however, rests immediately on the sand and grit beds. The connection may be traced to within a few feet, leaving at the utmost merely room for the intervention of a thin bed of shale. The limestone is prolonged and thins out towards the south-west beyond the actually developed limits of the sandstone, and becomes more distinctly stratified at Woodside, its extreme south-west point, where it is quarried and burnt. It is there interlaced with wayboards of shale, and dips S.E. 30°. The limestone of Nash is not conterminous with the sandstone on the east, but on the contrary expires at Nash, while the sandstone extends to Corton turnpike-gate.

At the foot of the limestone kilns at Nash, and almost covered by the detached masses of limestone falling or exploded from the cliff, is a mass of shale which would pass below the limestone if the latter were supposed to lie horizontally; but there can be no doubt, from the dip at Woodside and Haxwall, that the limestone is very highly inclined, and has been elevated by the same means and at the same time as the sandstone. The shale consequently lies above the limestone. It is not, however, as far as it can be traced, of any considerable thickness. The little river Somergil or Endwall, which drains the vales of Radnor and Knill, runs near the base of the cliff, and the beds are wholly obscured by an accumulation of gravel, covering the adjoining valley, on the south side of which undoubted Lower Ludlow beds rise, and dip gently to the south-east, succeeded by Upper Ludlow, and in the neighbourhood of Eywood and Titley overlaid by Old Red Sandstone. The position of the Lower Ludlow, and the fact that the adjacent valley of New Radnor is scooped out of an enormous accumulation of that formation, lead to the inference that the base of the valley of Knill is also of that age*.

Having traced an ascending section from the anticlinal ridge of Caen Wood southwards to the old red sandstone of Herefordshire, the deposits on the north or Presteign side require to be noticed. The limestone so beautifully developed on the south side is almost wholly wanting here. A thin band about eight feet thick occurs at the 'Sandbanks,' on the north-eastern side of the hill, and close to the former workings for this bed the sandstone is bared. The northern dip of the latter at this place has been already alluded to. This band of limestone dips 50° N.N.E., and is separated from the sand or grit beds by a few feet of shale, which also overlies it to a greater depth. The limestone band, which is highly crystalline, thins

* Sir R. Murchison has so laid it down in the text of his 'Silurian System,' and also in a section illustrating this district. See Sil. System, p. 314, and pl. 33, fig. 2.

out towards the west. Its former course towards Corton may be traced by the old workings on the south side of 'Folly Bank.' The shale also thins out towards the west, but in this direction the order of succession is disturbed by a fault which has let down an outlier of old red sandstone extending from 'The Slough' over the 'Deepmoors' to 'Radnor Wood.' Proceeding, however, from the Sandbanks in a north-easterly direction across the valley of the Lug to Stapleton Hill, a section may be obtained free from this fault, the line of which appears to be from above Brook House at Stapleton, south-west, to Presteign, Slough, and Radnor Wood, cutting off the Upper Ludlow and outliers of old red sandstone on its north-west, from the shale and Lower Ludlow on its south-east side. As from the intervention of the Knill valley on the south, so from that of Presteign drained by the Lug on the north, the precise thickness of shale and Lower Ludlow cannot be accurately determined. The shale has been washed away to within about fifty or sixty feet of the grit by the denudation of the Presteign valley. All that can be stated with certainty is, that leaving the shale at the 'Sandbanks' on the south side of that valley, at the distance of a little more than a mile to the north-east, the Lower Ludlow rock emerges at Stapleton Hill from the gravel, and dipping gently to the N.N.W. passes under Upper Ludlow beds in Hill Peak.

An ascending section on each side of the anticlinal line is thus obtained, which will be more clearly understood by reference to the annexed sketch.

Before proceeding to an examination of the fossil remains of Nash limestone, the *experimentum crucis* of this, as of every other similar geological problem, the evidence from position and structure may be considered.

The strongest fact on behalf of the lower character of the limestone, is doubtless that on one side it is in absolute contact with the Caradoc sandstone, and on the other is separated from the grit by only a few feet of shale. Notwithstanding this, however, I am led to retain my opinion that the Nash limestone is identical with that of Wenlock rather than Woolhope.

1. While the limestone strata of Woolhope and elsewhere are for the most part impure and only burnt when better cannot be obtained, that at Nash Scar is remarkably pure and highly crystalline. The mineralogical character of the Woolhope limestone given by Sir Roderick Murchison is this: "a hard, dark-blue, thick, flag-like limestone; the surfaces frequently chequered with transverse septa, occupied by pink calcareous spar." Not one of these terms is applicable to the formation at Nash. The yet more impure limestone occurring in the sandstone of the river Onney section, in Shropshire, and which beds, it is well to remember, are placed by Sir Roderick Murchison as forming the top of the Caradoc beds, not only on account of their position and organic remains, but also by reason of their mineral structure, could never be mistaken for that of Nash; and yet this is a fair comparison to make, for the beds of grit and sandstone of Caen Wood are the prolongation of the Caradoc district connected by the before-mentioned grit of Brampton Brian.

2. There is no passage from the sand and grits into the Nash limestone. In walking over Nash Scar, the limit of the sandstone wherever the surface is bared to the rock may be defined to an inch, and neither above nor below that boundary is there any trace of the sandstone on the one hand or of the limestone on the other. So on the north side of the hill, there is no interlacing of the shale with the grit, the escarpment of which presents a clear and decided face.

3. The Wenlock rocks from the point of their expansion in the Wigmore valley on their strike south-west towards Builth, are considerably contracted, and at Kinsham, about four miles north-east of Nash, merely occupy the gorge of the river Lug. At Nash, as already shown, the development of the shale is only sufficient to identify it, and it can scarcely be traced in the dislocated country of Old Radnor. Regarding then the limestone and shale as one formation, and bearing in mind the causes which produced in a former sea-bottom a calcareous rather than an argillaceous deposit, the fact that the limestone instead of the shale is at one spot brought into contact with the inferior nucleus of sandstone, cannot be a ground for refusing to regard the limestone as the equivalent of that of Wenlock.

The inference to be derived from an examination and comparison of the fossil contents of the limestone, remains to be considered. With reference to this branch of the question it may be premised, that there cannot be any question as to the age of the formations superior and inferior to the limestone and shale. The sandstone of Caen Wood contains the characteristic fossils of the Caradoc, including an abundance of the *Pentamerus oblongus*, Sow., *Atrypa hemisphærica*,

Sow., and various species of the genus *Orthis**. The beds of the Lower Ludlow rock are well marked at each end of the section by their fossils. In a quarry in the lane leading from Nash to Eywood, I have observed *Cardiola interrupta*, Sow., and *Orthoceras pyriforme*, Sow., and in the quarry on Stapleton Hill opposite Badland's Cottage, vast quantities of *Graptolithus Ludensis*, Murch., and *Terebratula navicula*, Sow., occur in two thin calcareous bands.

With respect to the shale, no question has been raised as to its being the equivalent of the Wenlock. In fact, the inference which has been drawn, that the Nash limestone is the equivalent of Woolhope, is derived in a great measure from the position of the Wenlock shale above it. The fossils of the shale at the Sandbanks on the Presteign side of the hill are—

Bumastus Barriensis, *Murch.*, fragments of which occur in great abundance.
Asaphus caudatus, *Brong.*
—— longicaudatus, *Murch.*
Calymene variolaris, *Brong.*
—— macrophthalma, *Brong.*
—— Blumenbachii, *Brong.*
—— tuberculata (?), *Murch.*
Cheirurus bimucronatus, *Murch.* sp.
Illænus —— ?
Nerita spirata, *Sow.*
Euomphalus rugosus ?, *Sow.*
—— funatus, *Sow.*
Orthis elegantula, *Dalm.* (O. canalis, *Sow.*, *Sil. Syst.*) †
Terebratula crebricostata, *Sow.*
—— reticularis, *Bronn.* (Atrypa affinis, *Sow.*)
Orthoceras canaliculatum, *Sow.*
—— Brightii, *Sow.*
Acroculia, n. s.
Natica spirata (*Sil. Syst.*) ?
Spirifer trapezoidalis, *Buch* (*Sil. Syst.*).
Turbinolopsis bina, *Lonsdale.*
Porites pyriformis, *Lonsdale.*
Graptolithus Ludensis, *Murch.*
Creseis —— ?

Of the Trilobites, the *Bumastus* and *Asaphus caudatus*, Brong., are by far the most abundant.

The shale at Nash contains fragments of *Calymene Blumenbachii*, Brong., *Asaphus caudatus*, Brong., and some uncertain species of Trilobites. The *C. Blumenbachii* occurs in great abundance. The same *Creseis* that occurs at the Sandbanks is met with here.

The fossils of the limestone at Nash and Woodside are—

*Nerita spirata, *Sow.*‡
Mytilus mytilimeris ?
*Pentamerus Knightii, *Sow.*
Terebratula nucula ?, *Sow.*
*—— lacunosa, *Sow.*
—— Capewellii, *Davidson.*
*—— crispata, *Sow.*
—— imbricata ?, *Sow.*
Orthis canalis, *Sow.*
—— orbicularis, *Sow.*
—— rustica, *Sow.*
—— pecten, *Dalm.*
Spirifer trapezoidalis, *Buch.*
*Atrypa affinis, *Sow.* (Terebratula reticularis, *Bronn.*)
—— hemisphærica, *Sow.*
—— linguifera, *Sow.*
*—— compressa, *Sow.*
Leptæna depressa, *Dalm.*
—— euglypha, *Dalm.*
*—— lepisma, *Sow.*
—— transversalis ?, *Dalm.*
Orbicula striata ?, *Sow.*
Orthoceras vertebrale, *Hall.*
*—— annulatum, *Sow.*

* The specimen of *Buccinum ? fusiforme*, Sow., figured in Murch. Sil. System, pl. 20. fig. 19, was discovered by me in this locality, where I have since found a second and larger specimen of this fine fossil.

† This is the Upper Silurian form: see De Vern. Geol. of Russia, p. 188.

‡ The fossils marked with an asterisk * are noticed by Sir R. Murchison as occurring at Nash. The others I have found since the publication of the 'Silurian System.'

The corals are—

*Limaria fruticosa, *Steing.*
—— clathrata, *Steing.*
*Porites tubulata, *Lonsdale.*
—— pyriformis?, *Lonsdale.*
Cyathophyllum dianthus, *Goldf.*
—— turbinatum, *Goldf.*
*Turbinolopsis bina, *Lonsdale.*
Favosites Gothlandica, *Lamk.*†

In addition to these, there are at Woodside fragments of gigantic *Crinoidea* of indeterminate genera.

The *Limaria* is so abundant at Nash, that it is evident the existence of the calcareous formation is due to that coral. None of the shells occur in abundance. At the time of the publication of the 'Silurian System,' only one specimen of the *Pentamerus Knightii*, Sow., had been observed; since that period three or four specimens have been obtained.

In the thin band of limestone at the Sandbanks I have found—

Orthis pecten?, *Dalm.*
Lingula quadrata?, *Eichw.*
Orbicula Forbesii, *Davidson.*

It is a remarkable fact that not a single specimen of the *Pentamerus lævis*, Sow., which is a most abundant fossil in the Caradoc sandstone of this district, has been met with in the limestone or shale. *Atrypa hemisphærica*, Sow., is the only characteristic fossil of the lower beds of sandstone that has found its way into the overlying shale, and the specimens of it in the latter are very rare.

If the question were merely, whether the Nash limestone was referable to the Upper or Lower Silurian system, it would scarcely admit of argument. *Terebratula crispata*, Sow., *Orthis rustica*, Sow., *O. orbicularis*, Sow., *Spirifer trapezoidalis*, Buch, *Atrypa compressa*, Sow., *A. linguifera*, Sow., and *Asaphus caudatus*, Brong., to say nothing of the *Limariæ*, not one of these fossils having ever been found in Lower Silurian rocks, prove that the Nash limestone is undoubtedly a member of the upper system; and if the Woolhope limestone were still to be ranked as the upper bed of the Caradoc sandstone, there would be an end of the question. Mr. Phillips, however, in his elaborate and valuable memoir on the Malvern Hills‡, has laid it down as beyond dispute that the Woolhope limestone is the lowest member of the Wenlock series; and if the correctness of this be admitted, the question now under consideration becomes one of very great nicety, in the determination of which the evidence derived from the actual position of the beds acquires greater weight, while the variation in the organic contents must be necessarily of a very limited extent.

To the argument, however, derived from the position of the limestone immediately above the sandstone, I answer, that the whole of the Wenlock series is so thinned out at this spot as not to admit of any separation into upper and lower beds, and that the limestone and shale may be said to rise from beneath the Lower Ludlow rock§ with

† In determining the species of the various fossils of the localities, I am indebted in a great measure to the kind assistance of Mr. D. Sharpe.

‡ Memoirs of the Geological Survey, vol. ii. pt. 1. pp. 74, 169.

§ This is the precise expression used by Sir R. Murchison.

as much truth as that they repose upon Caradoc sandstone. If the Nash limestone be the equivalent of the Woolhope, then the Wenlock limestone is wholly omitted,—a singular circumstance, considering the close vicinity of undoubted Wenlock beds at Kinsham, as already observed.

Among the fossils of Nash limestone which have not been hitherto noticed in the Woolhope limestone or its equivalents, or in the beds below it, are—

Mytilus mytilimeris?
Pentamerus Knightii, *Sow.*
Orthis orbicularis, *Sow.*
—— rustica, *Sow.*
Leptæna euglypha, *Dalm.*
—— lepisma, *Sow.*
—— transversalis?, *Dalm.*
Orbicula striata?, *Sow.*
—— Forbesii, *Davidson.*—Sandbanks.
Porites tubulata, *Lonsdale.*
Cyathophyllum dianthus, *Goldf.*
Limaria clathrata, *Steing.*
—— fruticosa, *Steing.*
Favosites Gothlandica, *Lamk.*

On the other hand, the only fossils of the limestone at Nash, Woodside, and Sandbanks which have not as yet been found in Wenlock limestone or superior strata, are—

Orthoceras vertebrale?, *Hall.*
Mytilus mytilimeris (Wenlock shale).
Atrypa hemisphærica, *Sow.*
Terebratula Capewellii?, *Davidson.*
Lingula quadrata?, *Eichw.*

The great abundance of the *Limaria clathrata*, Steing., is a strong fact to overcome in removing the Nash limestone to the bottom of the shale. One inference seems evident: if the Nash limestone is the equivalent of the Woolhope, there is no specific distinction between the organic contents of the two formations of Wenlock and Woolhope.

June 5, 1850.

His Grace the Duke of Argyle was elected a Fellow.

The following communications were read:—

1. *On* British Fossil Lepadidæ. By C. Darwin, Esq., F.R.S. G.S. &c.

[This paper was withdrawn by the author with the permission of the Council.]

[*Abstract.*]

Mr. Darwin noticed that great confusion exists in the nomenclature of the comparatively few species of Cirrhipeds, hitherto found in a fossil state; arising both from the easy separation of the several dissimilar valves soon after the death of the animal, and from the imperfect characters afforded by the valves themselves, which are, as it were, but parts of the crustacean carapace, neither accompanied with, nor distinctly impressed by, any of the soft parts of the animal. He then pointed out such particular valves as were sufficiently distinct, and had sufficiently constant characters to be considered as charac-

teristic of genera,—as, for instance, the keel, or dorsal, valve in *Scalpellum*, and the scutal, or inferior lateral, valve in *Pollicipes*. The pedunculated cirrhipeds (*Lepadidæ*) were stated to have made their first appearance in the lower oolite, and to have reached their culminant point in the cretaceous epoch. The absence of sessile cirrhipeds in the earlier and secondary formations, and their occurrence for the first time in the eocene deposits, were then noticed, the author dwelling on the characters of the genus *Verruca*, and pointing out that, as the type of a group intermediate between, and of equal value with, the sessile and the pedunculate cirrhipeds, it offered no real exception to the rule that sessile cirrhipeds do not occur in the secondary formations; but that, on the contrary, it harmonizes with the law of relation between serial affinities of animals and their first appearance on this earth. Mr. Darwin concluded with a few observations on the comparative ranges of recent and fossil cirrhipeds, and on the close affinities between the extinct and the living forms.

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2. *On the* Tertiary Strata *and their* Dislocations *in the Neighbourhood of* Blackheath. By the Rev. H. M. De la Condamine, M.A., St. John's Coll., Camb.

[Communicated by Sir H. T. De la Beche, V.P.G.S.]

The cuttings of the North Kent Railway yielded some good sections of the Plastic Clay series, and disclosed an important line of dislocation at Deptford;—important because a close approximation to its date can be obtained, and because it has affected the present configuration of the adjoining country. The abrupt escarpment of the chalk and plastic clay along the south side of the Thames is manifestly due in some measure to this dislocation, which also accounts for the presence of the London clay under the Greenwich marshes at an unexpectedly low level.

Before proceeding to consider the effects of this dislocation, it will be well to describe the strata which it has affected. And this description derives interest from the fact that these strata are perfectly regular over a large extent of country; their order of superposition and organic contents being constant, and their mineral composition exhibiting no great variation. Table I. shows the localities where the succession of strata may be most advantageously studied; and Table II. the correspondence between the subdivisions existing in this district and those observed elsewhere, and recorded by Mr. Prestwich*.

* Quart. Journ. Geol. Soc. vol. ii.

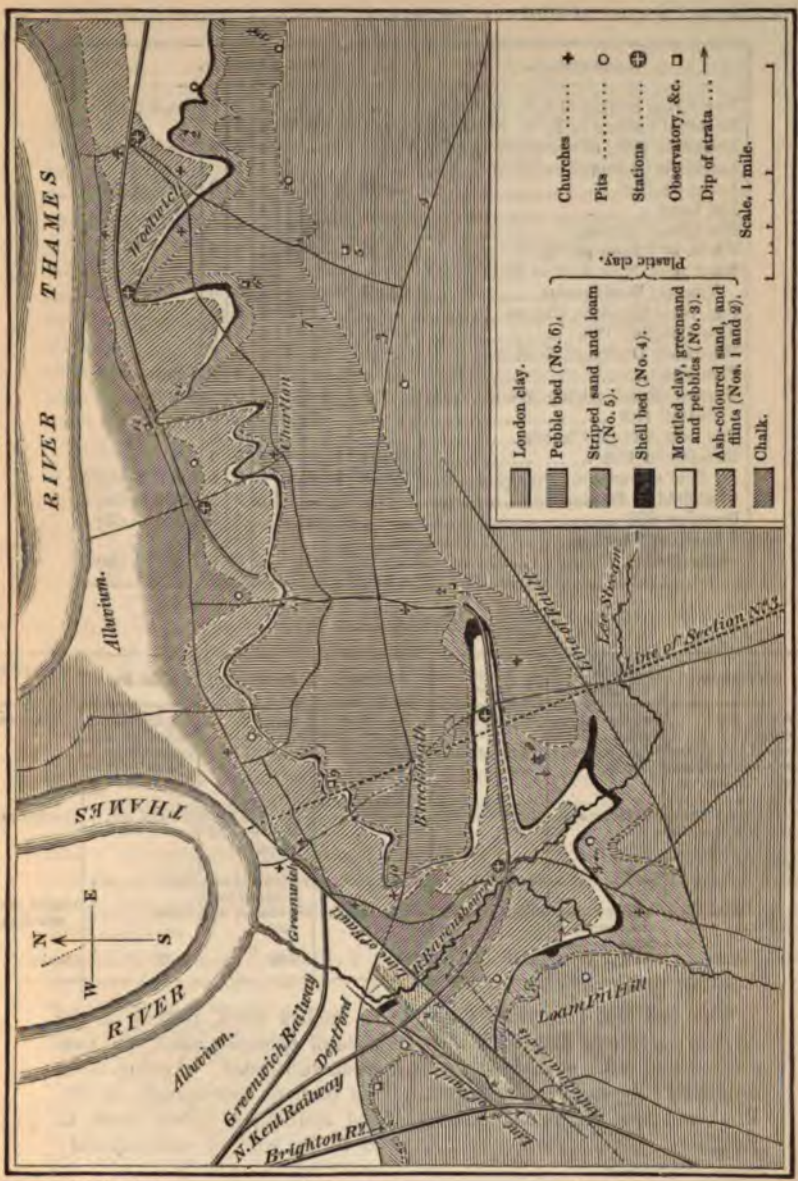


Fig. 1.—*Geological Map of the Environs of Blackheath.*

N.B. The beds Nos. 3 and 4 are given on a somewhat increased scale from the "Turnpike" as far as "Blackheath Point."
The line of fault passing through Greenwich probably trends to the E.N.E. at a short distance beyond the town.

2. Morden College.
3. Shooter's Hill Road.
4. Shooter's Hill.
5. Royal Military Academy.
6. Rotunda.
7. Woolwich Common.
8. Plumstead Common.
9. Observatory.
10. Blackheath Point.
11. Turnpike (New Charlton).

TABLE I.

LOCALITIES.	BEDS EXPOSED.							
New-Cross cutting of S. E. Railway...	.....	...	...	...	4	5	6	London clay.
Deptford cutting of N. K. Railway...	Chalk	...	2	3	4	5		
Brickfield S.W. of the above	.....	...	...	...	4	5	6	London clay.
Leigh's brickfield, Lewisham	.....	...	...	3	4	5		
Loam-pit Hill	Chalk	1	2	3	4	5	6	London clay.
Lee Lane	.....	...	...	3	4			
Blackheath cutting	.....	...	2	3	4	5		
Pit N. of Vanburgh Fields	.....	...	2	3	4	5	6	
Road near N.E. end of Blackheath Tunnel (Woodlands)	Chalk	1	2	3	4	5	6	
Pits W. of Charlton Church.....	.....	...	2	3	4	5	6	
New Charlton Pits	Chalk	1	2	3	4	5	6	
Woolwich Dockyard Station	.....	...	2	3	4	5	6	
Plumstead.....	.....	...	2	3	4	5	6	London clay.
Harrow Road, Abbey Wood; and Bostall Hill	.....	...	2	3	...	...	6	
Pits near Eltham Church.....	.....	...	...	...	...	5	6	
Chiselhurst Hill	Chalk	1	2	3	4	5	6	
St. Paul's Cray and Orpington	Chalk	1	2	3	4	5	6	London clay.
Brickfield at Farnborough	.....	...	...	...	...	5	...	London clay.
Bromley Hill	.....	...	...	...	...	5	6	London clay.
Addington Heath.....	.....	...	...	...	...	5	6	
Beckenham	.....	...	...	...	...	5	6	London clay.

TABLE II.

	Blackheath.	Kingsdon and Hungerford.	Basing-stoke.	Hertford.	Newhaven.	Alum Bay.	White Cliff Bay.
	London clay.....	London clay ..	London clay ..	London clay ..	.....	London clay...	London clay.
6.	Pebble bed	Pebble beds ..	.....	.....	.....	Rolled pebbles.	
5.	Striped yellow and grey sand and loam (with lignite).	Light-coloured sands.	Light-coloured sands.	Sands	.....	Yellow sands (with lignite).	
4.	Shell-bed	.....	.....	.....	Shell-beds....		
3.	Mottled clay, green sand and pebbles (with lignite and selenite).	Mottled clays..	Mottled clays ..	Mottled clays ..	Clay beds (with lignite and selenite).	Mottled clays..	Mottled clay.
2.	Ash-coloured sand	Sand	Sand	Sand	Yellow and ash-coloured sand	Sand	Yellow sand and flints.
1.	Green-coated flints and sand.	Conglomerate of flints, green & ochreous sand.	Flints	Flints, &c.....	Greensand and flints.	Flints	
	Chalk.....	Chalk	Chalk	Chalk	Chalk	Chalk	Chalk.

The bed No. 1 is from four to ten inches thick, resting on the uneven surface of the chalk. It consists of greenish sand, and partially rolled flints coated with a dark green substance. Among these are frequently casts of Echinites. This perhaps corresponds, as Dr. Buckland has suggested, with the bed containing fishes' teeth at Reading *. Here however it appears to be void of contemporary organic remains.

No. 2 is a mass of whitish or ash-coloured sand, varying from 30 to 58 feet in thickness. Its stratification is seldom distinct until

* Trans. Geol. Soc. vol. iv. p. 278.

it has been exposed to the weather. Its colour is caused by the presence of numerous grains of an opake black or dark green substance, the majority of grains being white transparent quartz, with a few yellow grains, and particles of selenite. This bed is often traversed by ferruginous strings; and near the Blackheath Station is intersected by hard black irregular veins, occasionally forming concentric layers and concretions. This condition may however have been induced after the denudation of the upper beds, exposure to moisture having frequently produced a deceptive appearance of stratification in this bed, as for instance, in the pit in Hyde Vale, Greenwich, and in the cutting east of Lewisham Station. Its surface suffered partial denudation before the deposition of No. 3, as may be seen in the N.E. pit on Loam-pit Hill; and this condition was strikingly evident in the Blackheath cutting before the sidings were trimmed. Organic remains do not occur, unless we credit the workmen's report that fragile casts of large shells are occasionally found near the base of this stratum at Charlton.

No. 3 is extremely variable in appearance and composition, though it has some constant characteristics:—

1. It always contains more or less *green* sand or clay.
2. It always contains pure calcareous matter, in layers, nodules, or concretions.
3. It indicates a less tranquil period than those preceding and succeeding it.

Near Woolwich Arsenal* and at Loam-pit Hill, the base of this bed is full of rolled flint pebbles imbedded in greenish sand; elsewhere the pebbles are not so numerous, though never entirely absent†. The upper part of this bed best deserves the name of "mottled clay," layers of red, green, yellow, and brown clay and sand succeeding each other in some localities with the greatest irregularity. This was seen especially in the Blackheath cutting, where the "false" or oblique stratification was strongly marked, and caused many slips during the excavation. At Morden College the sand was of a brilliant green hue. At Loam-pit Hill the upper part of the bed abounds in soft nodules of white and cream-coloured friable marl. At Deptford it is partly disseminated in the green clay, and partly concentrated into hard nodules.

At Charlton and Woolwich the contained calcareous matter (besides forming soft nodules and streaks) has combined with oxide of iron to form hard concretions, some branching, some concentric, and occasionally enclosing *Cyrenæ*. In the grounds lately occupied by Sir W. Gosset, the concretions form a nearly continuous mass of stone; there is little or no clay even in the upper part of the bed, and it closely resembles the striped sand No. 5. In Mr. Angerstein's road (Woodlands), where a beautiful section of all the beds has been made, the concretions are large, black, and spheroidal.

* The denudation of No. 2 here has been very great.

† Near the W. Woolwich Station the lower part of this bed becomes hardly distinguishable from No. 2, although the presence of a few pebbles fixes the line of demarcation.

At Charlton this bed contains a little selenite, large crystals of which were also met with in a well sunk on the east side of Blackheath. In the Blackheath cutting a large quantity of pyritous lignite was found in one of the hollows worn in the surface of No. 2 before the deposition of this bed. The thickness of this bed varies from six to twenty feet. It is worked for bricks between Plumstead and Woolwich.

No. 4, the Shell-bed, is the great deposit of organic remains of this formation. Its appearance and contents at Woolwich and Charlton are well known. It is also well developed at Deptford, where the lower part is blue and argillaceous, the upper yellow and sandy. In the former, the interstices between the *Ostreæ* are often filled with yellow calcareous spar. The upper part contains the best-preserved fossils, the sandy matrix having protected even the ligament* of the *Cyrenæ*, and the coloured markings of the shells being occasionally preserved in the more compact and stony layers. Rolled pebbles are here mixed with the shells, together with fragments of vegetable matter.

At Loam-pit Hill this bed appears as a chocolate-coloured mass of crushed shells, with a layer of *Ostreæ*, *Cerithia*, and *Cyrenæ* imperfectly preserved.

At Lee it is a hard limestone (known to well-diggers as "the cockle"), capped with a layer of crushed shells, which in Blackheath Park resembles ill-mixed mortar.

At Morden College it expands to the thickness of eight feet, consisting of blue shelly clay, with a few stripes of sand containing as usual the most perfect shells. The *Cyrenæ* are often filled or lined with sparkling pyrites. The *Cerithia* appear to affect the neighbourhood of the *Ostreæ*, as if the former had been rolled along by a current until they stopped against the larger shells. The existence of such a current is attested by the rolled pebbles in this bed at Deptford.

In the late Sir W. Gosset's grounds at Charlton, this bed consists entirely of broken *Ostreæ* resting on the very irregular surface of the bed No. 3. It thins out and disappears east of Plumstead.

I have procured the following fossils from this bed †:—

Cyrena Gravesii, *Desh.*
*—— cuneiformis, *Fér.*
—— trigonula, *Wood.*
—— (uncertain, intermediate in character between the last two).
Ostrea pulchra, *Sow.*
*—— edulina, *Sow.*
*Melania inquinata, *Defr.* (4 var.)
Rostellaria.
*Cerithium crenatulatum, *Desh.*
*Potamides variabilis, *Desh.* sp.
*Melanopsis ancillaroides, *Desh.*
*Rissoa, and a few uncertain species.
*Wood.

* These occur in "No. 5."

No. 5 is a distinctly stratified bed of yellow sand and loam, the latter sometimes lead-coloured; the stratification is often marked by thin laminæ of clay. It abounds in concretions, pyritous at

* The microscope has shown that the animal matter in these ligaments has been beautifully and exactly replaced by carbonate of lime.

† I am indebted to Prof. E. Forbes for most of the names.

Loam-pit Hill, ferruginous and concentric towards Charlton. In the former locality there are traces of wood and leaves in the lower part of the bed; but its principal organic contents occur occasionally in the upper part. At New Cross this consists of the alternation of yellowish sand, dark clay, and shells, with concretions* containing freshwater shells, described by Mr. Warburton in 1845. In the brickfield S. E. of the Naval School, the same beds appear, containing—

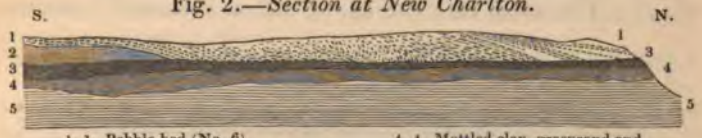
*Cyrena cuneiformis, *Fér.*
*Ostrea edulina, *Sow.*
*—— Bellovacina, *Lamk.*
—— elegans, *Desh.*
*Modiola elegans, *Sow.*
Unio Solandri, *Sow.*
Paludina Desnoyersi, *Desh.*
*Cerithium crenatulatum, *Desh.*
*Buccinum.
*Melanopsis ancillaroides ?, *Desh.*
Calyptræa trochiformis, *Lamk.*
*Rissoa.
Fragments of fish-bone.
*Wood.
Traces of seeds.

At Lee, where the bed is twenty-five feet thick, the upper part contains patches of shells, mostly crushed, but sometimes beautifully preserved, and retaining even the colour when first exposed. Of the fossils which I have found here, eight are identical with those in the preceding list†; the rest are—

Potamides variabilis, *Desh.*
Melania inquinata, *Defr.*
Neritina pisiformis, *Fér.*
Natica.
Fusus.
Teredo.
Teeth of Lamna contortidens, *Agass.*

This bed has suffered much irregular denudation before the deposition of No. 6. At one spot (near the turnpike at Charlton) it has been entirely swept away. (See fig. 2.) On Blackheath an insu-

Fig. 2.—*Section at New Charlton.*



1, 1. Pebble bed (No. 6).
2. Striped sand and loam (No. 5).
3, 3. Shell bed (No. 4).
4, 4. Mottled clay, greensand and pebbles (No. 3).
5, 5. Ash-coloured sand (No. 2).

lated portion of it retains its original thickness, while at the distance of half a mile, only three feet have been spared. (See Map, fig. 1.) It has suffered to the same extent at Bostall Hill. (See Table I. p. 442.)

No. 6 is an irregular bed of rolled flint pebbles and sand, with a few pebbles of quartz; sometimes it is entirely wanting‡. At Loam-pit Hill it is represented only by an occasional line of pebbles. At New Cross it is from two to four feet thick. On Blackheath it swells out to forty or fifty feet, frequently filling spaces once occupied by No. 5.

* Since the above was written, I have found this bed of concretions at New Peckham, where a mass of *Paludinæ* and *Cyrenæ* is exposed in a brickfield.

† Viz. those marked with an asterisk.

‡ Mr. Prestwich has called this "the Basement-bed of the London clay."

The pebbles in some places, where but little sand is present, are spotted or pock-marked (if I may use the expression), perhaps by the protection which where in contact they afford each other from the action of percolating water. At the points of contact they often adhere to each other, their surfaces breaking away when separated. Occasionally they are cemented together in a hard conglomerate. The pebbles are often of such magnitude (from 4 to 6 inches diameter) as to indicate rapid motion of the water, and are deposited at a high angle, amounting in one spot to 25°*. On the other hand, beds of fine "pea-gravel," sand, and even clay (as in the above-mentioned spot), indicate intervals of comparative tranquillity. It is under such conditions that organic remains occur, as in the well-known bed at New Charlton (which has replaced No. 5—see fig. 2) containing semi-fluviatile shells. Some of these are in one spot in the position of living animals, the *Ostreæ* adhering to the upper surface of the pebbles, and the anterior slope of *Cyrena tellinella* being uppermost. Among the pebbles near this are rolled fragments of *Ostreæ*. The following fossils occur:—

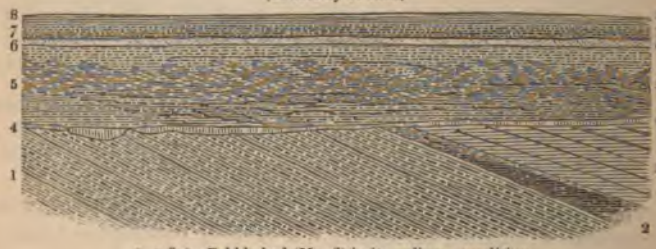
*Cyrena cuneiformis, *Fér.*
—— tellinella, *Fér.*
Pectunculus Plumsteadiensis, *Sow.*
Ostrea flabellula, *Lamk.*
—— (uncertain).
*Cerithium crenulatum, *Desh.*
*Potamides variabilis, *Desh.* sp.
*Melanopsis ancillaroides, *Desh.*
*Neritina pisiformis, *Fér.*
Natica.
Buccinum.
Turritella?
*Teeth of Lamna contortidens, *Agass.*

* These occur in the beds previously described.

Similar deposits appear in the vale north of Shooter's Hill, opposite Sir Edward Pellatt's Gate, on Blackheath east of the south entrance to Greenwich Park (see fig. 3), and on Plumstead Common.

Fig. 3.—*Section in a Pit on the South side of Greenwich Park.*

(30 feet by 16 feet.)



1, 5 & 7. Pebble bed (No. 6) in its ordinary condition.
2. Bed of pebbles, with shells in the darker part.
3. Grey laminated sandy loam.
4. Irregular indistinct line of brown sand.
6. Reddish mottled loam with a peculiar saline taste.
8. Alluvium.

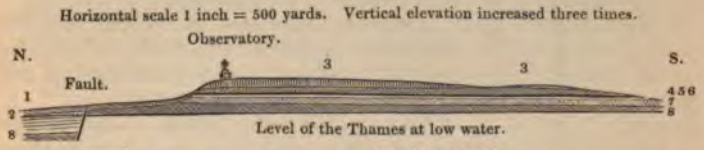
From this pebble-bed much of the more recent gravel in the neighbourhood has been derived, but the latter may always be distinguished

* The dip of this "false stratification" varies on Blackheath to every point of the compass.

from it by the presence of *imperfectly* rolled flints, which never occur in the tertiary bed.

Thus we have a distinct line of demarcation between the Lower and Middle Eocene periods, "during which," as Mr. Prestwich has observed, "the water acquired greatly increased transporting power, and after which the London clay was deposited in a more tranquil and perhaps a deeper sea."

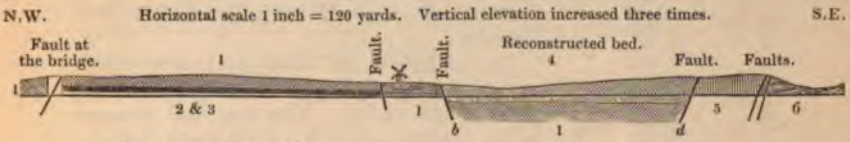
Fig. 4.—*Section across Blackheath.*



1. Gravel.
2. London clay.
3. Pebble bed (No. 6).
4. Striped sandstone (No. 5).
5. Shell bed (No. 4).
6. Mottled clay, green sand and pebbles (No. 3).
7. Ash-coloured sand and flints (Nos. 1 & 2).
8. Chalk.

The date of the dislocation of these strata is posterior to that of the partial denudation of the London clay. This will appear by comparing the Map with the Section of the faults at Deptford. Be-

Fig. 5.—*Section of the Lines of Dislocation at Deptford.*



1. Striped sand and loam (No. 5).
2. Shell bed (No. 4).
3. Mottled clay, green sand, and flints (No. 3).
4. Sandy loam.
5. Ash-coloured sands (No. 2).
6. Chalk.

tween the lines *a b*, *c d* (see Map) there is a nondescript mass, which tallies with none of the neighbouring strata, but which is just what would result from the degradation and mixture of the striped sand, No. 5, and the London clay. I therefore suppose the trough or trench formed by the subsidence, real or comparative, of the original surface between *a b* and *c d* (see figs. 5 and 6), to have been filled up by the waste of the adjacent beds; for had the London clay suffered no denudation, it would occupy the space in question: whether or not a remnant of it exists beneath the line of railway, remains to be proved. This supposition is favoured by the indistinct basin-like stratification of the sandy loam between *b* and *d*. There are also a few pebbles in it, which may well have been derived from No. 6. I have not however observed any fragments of the shell-bed.

The line of demarcation at *d* (see Section, fig. 5) is indistinct, the edge of the fractured bed of sand, No. 2, having of course been soon obliterated by the action of water. It is interesting to observe that at *b*, the tough strata of No. 5 bent before they yielded to the tension.

The intensity of the force by which this dislocation was effected,

Fig. 6.—*Section of the Line of Dislocation South of New Cross.*

Horizontal scale 1 inch = 140 yards. Vertical elevation increased three times.
Second bridge from New Cross.
N.
S.
Reconstructed bed.
Fault.
Anticlinal axis.
Brighton Railway.
Freshwater concretions.
Freshwater concretions and lines of shells in bed "No. 5."
1. London clay.
2. Pebble bed (No. 6).
3. Striped sand and loam (No. 5).
4. Sandy loam.

appears to have been greater towards the N.E., and less towards the S.W.; for whilst it is probable that at Deptford the displacement does not exceed 90 feet, at Greenwich it is about 120 feet (see Section, fig. 6), and in the Greenwich Marshes 160 feet; the chalk being 124 feet from the surface at Greenwich Hospital*, and 55 feet of London clay having been pierced in the Marshes.

South of New Cross, on the contrary, the dislocation (which at Deptford produced six faults) is reduced to a few undulations and one fault. (See Section, fig. 6.)

About a mile and a half south-east of this line of disturbance, and parallel to it, there ranges another line of fault, a section of which was formerly to be seen near the lane behind Morden College, and near the Tiger's Head at Lee. The effect of this dislocation is that the London clay occupies all the low ground drained by the Lee Stream, a position not due to it by the dip of the strata, which does not exceed 2°. There is evidence of the existence of faults near Eltham, Chiselhurst, and Bromley.

In the hollow of Tranquilvale is a reconstruction of the strata which crop out in the sides of the valley. This was well exposed in the cutting east of the Blackheath Station.

The section (fig. 7) exhibits the contortions of part of this reconstruction, the undisturbed bed at the base being the ash-coloured sand (No. 2) with ferruginous strings and concretions. The fragments of shell are derived from No. 4; the coloured clay and greensand from No. 3.

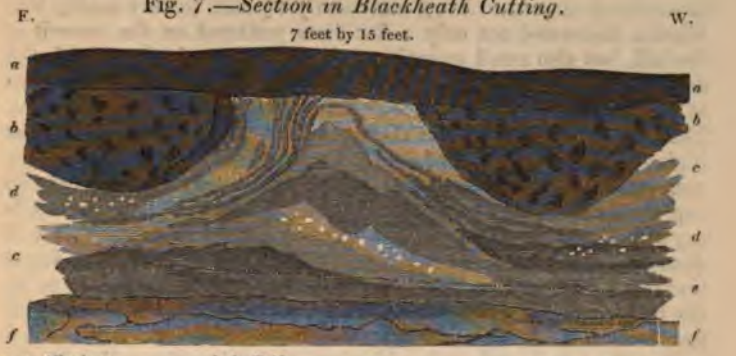
These contortions may be owing to glacial action; and there is evidence of action of the same kind in the centre of Blackheath. It is not impossible that the few feet of loam, &c. which there lie on the pebble-bed may be a reconstruction (if not the commencement) of the London clay.

All the low ground about the Lee Stream

* The following series of beds were penetrated by the well at Greenwich Hospital: alluvium, 10 feet; gravel (drift or "pebble-bed"?), 35 feet; black sand, blue clay, and shelly rock (equivalent to No. 4), 9 feet; red clay, white sand, and green sand and pebbles (No. 3), 12 feet; sand (No. 2), 57 feet, resting on chalk.

is strewed with drift-gravel (chiefly derived from No. 6), capped by a reconstruction of the London clay, which might easily be mistaken

Fig. 7.—*Section in Blackheath Cutting.*



a, *a*. Alluvium. *b*, *b*. Drift.
c, *c*. Coloured clay and green sand, derived from "No. 3," with fragmentary shells (*d*) from "No. 4," and pebbles (*e*).
f. Ash-coloured sand with ferruginous lines and concretions.

for that bed *in situ*. In consequence of this drift, the sections made by the stream are of little value, though occasionally the stream has worn its way down to the true tertiary substratum.

Hence the Map cannot give the boundary-lines of the strata with certainty on the low ground; elsewhere I trust that it will be found to be as correct as the scale permits.

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3. *On the* Diluvia *and* Valleys *in the Vicinity of* Bath. By Charles Henry Weston, Esq., F.G.S.

[Abstract.]

Mr. Weston met with beds or considerable masses of chalk-flint diluvium on the crest of Kingsdown, one of the hills forming the eastern side of the Box Valley, about five miles from Bath. The drift was *in situ* on the upper portion of the Great Oolite, and filled up a trough or "gulley." With the exception of occasional masses of Great Oolite, it consisted entirely of chalk flints with ferruginous clay. Some of the flints were rounded and some were brecciated, while others, although smoothed superficially, retained their original forms of polypothecian organization so characteristic of the chalk formation. Mr. Weston could detect no fossils in this deposit. The height of these beds, determined by barometrical admeasurement, was found to be 545 feet above the level of the river Avon. The oolitic rock on which these drift beds are deposited is superficially much hollowed and apparently waterworn; its stratification is horizontal, and it is traversed with superinduced cross joints and fissures. In a quarry that had been worked under the hill and contiguous to the bed of

chalk-flint gravel, the latter was found to have penetrated from above and filled up the fissures of the roof and sides down to the floor.

On Farleigh Down, a higher portion of the same range, hanging immediately over the Avon, and nearly 1½ mile further south, Mr. Weston discovered not only a few flints scattered on the summit of the hill, but also small quantities of chalk-flint mixed up with the debris of the oolitic rocks, and partially converted by the infiltration of water charged with carbonate of lime into a conglomerate or breccia. This deposit is about 629 feet above the river, and consequently 84 feet higher than that on Kingsdown. There was also a strong ferruginous tint imparted to the upper surface of the oolitic rocks where no superincumbent clay and gravel existed. The superficial tint extending over the Great Oolite on the western side of the Box Valley of denudation and eastward towards the chalk range over the forest marble of Wilts, noticed by Conybeare and Phillips *, appears to be the remains of the same diluvium which has to a greater extent been preserved at Kingsdown.

Mr. Weston describes the diluvium occupying the valley of the Avon as consisting of a few chalk flints, fragments of greensand, oolite, lias, carboniferous limestone, millstone grit, and old red sandstone; indeed, to use Mr. Lonsdale's words †, "of every formation from the Wiltshire Downs to the Mendip Hills;" the great mass, however, of this gravel consists of oolitic debris; the chalk-flints are very rare, and, if the Kingsdown diluvium were described as composed of chalk-flints exclusively, the valley diluvium might with nearly equal truth be said to consist of almost everything except chalk-flint.

This valley drift may be traced on both sides of the Avon; some of its beds being not far above the level of the river, and others at considerable elevations. Fossil remains of *Elephas* and *Rhinoceros* have been found in the gravel on both sides of the valley; the other organic remains found in this deposit are of *Sus*, *Equus*, *Bos*, and *Ursus* ? ‡

The section of this gravel made by the railway cutting near the Hampton rocks exhibits beds of fine gravel and coarse sand, having a horizontal stratification; the pebbles generally being arranged upon the subjacent lias according to their size and weight. In the bed nearer the river the gravel is less regularly disposed, the larger and smaller pebbles being confusedly mingled together.

Mr. Weston remarks that the chalk-flint drift was probably deposited over the oolitic district prior to the excavation of the existing valleys, and during, perhaps, the *earlier* part of the eocene period; that its source must have been the chalk hills near Devizes; and the cause of its production the westerly currents resulting from the elevation of the *northern* anticlinal axis of the south-east of England, viz. that of the valleys of Kingsclere, Ham, and Pusey.

* Outlines of the Geology of England and Wales.
† Trans. Geol. Soc. vol. iii. pt. 2. 2nd Ser. p. 271.
‡ Lonsdale, *loc. cit.* p. 271.

With regard to the valley drift, the author observes, that the localities in the neighbourhood of Frome could readily supply the various constituents of this heterogeneous gravel. On the east and south-east of Frome the flanks of the chalk range consist of greensand, and somewhat on the west of Frome the millstone grit and carboniferous limestone are exposed; whilst between Frome and Bath the forest marble and the great and inferior oolites occur. Aqueous currents setting towards the north from some region south of Frome would act on the several formations mentioned, and eventually transport to the Bath valleys a deposit similar to that now reposing in them. From the account of the disposition of the beds before given, it appears that the portion of the deposit nearer the river was formed during powerful aqueous action, which to a great extent interfered with the law of gravitation, while the portion nearer the Hampton hill was precipitated under calmer circumstances, and, at times, during complete quiescence. These are just the conditions which might be expected to result from a northerly current, the force of which would act more violently towards the centre of the valley, whilst the position of Claverton and Hampton Downs would produce a counter-current or backwater which would afford different degrees of calmness. The cause of these northerly currents the author ascribes to the elevation of the *central* anticlinal axis of the south-east of England, viz. that of the Weald. He considers also that the valley drift was contemporaneous with the excavation of the valleys themselves, and, as evidenced by its organic remains, of the pliocene age.

The author concludes with some observations on the geological age of the river Avon, remarking that the Avon probably dates its origin from the elevation, and consequent change in the local stratification, of the oolitic hills of Gloucestershire, and that the river, when it first took its present direction, merely flowed over an already formed valley-bed.

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4. *On the Occurrence of a* Freshwater Bed *of* Marl *in the* Fens *of* Cambridgeshire. By W. J. Hamilton, Sec. G.S.

My attention having been repeatedly directed to a peculiar bed of white, chalky-looking marl, partly overlying and partly interstratified with the black peaty soil through which the East Anglian Railway has been cut between Ely and Lynn, or rather between Littleport and Downham, I determined to examine the nature of the bed. With this view, I obtained a quantity of the marl in question for the purpose of examination. The bed is seen soon after leaving Littleport, and may be traced continuously for many miles, varying considerably in thickness, from about a foot, as well as I could judge, to three or four inches. In some places it is seen on the surface, in others it approaches it so nearly as to be turned up with the plough, while in others again it is two or three feet below the surface. Whether this difference is owing to the undulations of the ground or of the bed itself, I was unable to ascertain; I am, however, inclined to attribute

it to the surface only. To what distance right and left of the railway it extends I have not yet been able to learn, but it is evidently very considerable. This however is certain, that whereas it was deposited subsequently to the great portion of the black peaty soil, it has been again covered up by a subsequent deposition of the same black substance.

On washing out the marl I found a considerable number of land and freshwater shells, of existing species. The following I have already found:—

Helix pulchella, *Müller*.
Limnæus stagnalis, *Drap.*
—— pereger, *Drap.* (two varieties).
Planorbis marginatus, *Drap.*
—— vortex, *Müller*.
—— carinatus, *Müller*.
Planorbis lævis, *Alder*.
Bithynia tentaculata, *Linn.* sp.
Physa fontinalis, *Drap.*
Valvata cristata, *Müller*.
Pisidium pusillum, *Turton*, sp.
—— obtusale?, *Lamarck*, sp.

Innumerable seed-vessels of *Chara* (*Gyrogonites*); and numerous *Entomostraca**, among which are *Cypris minuta*, Baird; *C. aurantia*, Jurine; *C. setigera*, Jones; *C. gibba*, Ramdohr; *Candona lucens*, Baird; and *Candona reptans*, Baird†.

We have thus evidence of the alternation of two freshwater deposits of different characters; and it becomes an interesting subject of inquiry, whence the white marl was derived of which one of the deposits consists. I supposed it was derived from the chalk brought down by the various rivers which from the surrounding hills flow into this low district, but neither Dr. Mantell nor Mr. Bowerbank, who have obligingly examined it, have been able to detect any remains of the Microzoa which abound in that formation, and would probably have remained uninjured had the white marl been derived from that source.

That the whole of this district has been covered by the water of the sea previous to the draining to which the country has been subjected, and probably at no very distant period, has always been admitted‡. A very slight oscillation in the level of this tract of country would have the effect of raising it for a time above the influence of the highest tides, and thus a portion of the district may have been temporarily converted into a freshwater lake or marsh. The abundance of the stems and seed-vessels of *Chara* shows that it must have been for a long time protected against all marine irruptions; and the great abundance of the fossil shells in all ages of growth proves that they were not merely washed into the basin, but that the district must have been for a considerable space of time covered by fresh water. I am aware of the meagreness of this account, but I thought the fact alone, as adding to our knowledge of the successive deposits of the surface of our own country, sufficiently interesting to justify my laying these observations before the Society.

P.S. Since the above notice was read I have received the following

* For the examination and determination of these minute fossils I am indebted to the kind attention of our curator, Mr. T. Rupert Jones.

† See Ann. Nat. Hist. ser. 2. vol. vi. p. 28.

‡ Ansted's Geology, vol. ii. p. 499.

additional information from the same gentleman who forwarded me the marl in the first instance.

The upper peat averages about twelve inches in thickness. The white marl runs about fifteen inches thick; but in some places it is nearly five feet thick. The black peat under the marl varies from three to seven feet in thickness; and under it is said to lie a blue soft clay. This formation extends about two miles on the west, and $1\frac{1}{4}$ mile on the east of the railway, and for about seven miles in length.

June 19, 1850.

The following communications were read:—

1. *On a* Section *of the* Lower Greensand *at* Seend, *near* Devizes. By William Cunnington, Esq.

[Communicated by Joseph Prestwich, jun., Esq., F.G.S.]

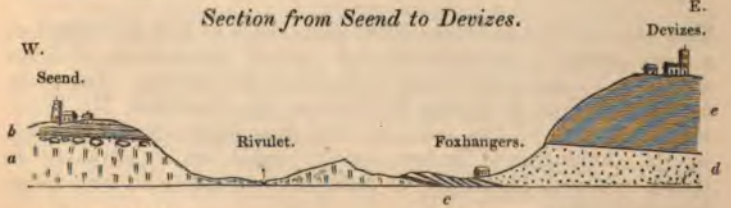
Having during the past winter made some observations on the sections exposed in the cutting of the road, at Seend, near Devizes, I now send you the result. I feel it important that this information should be recorded, or it will be altogether lost; the section having already been for some time covered up.

The cutting was not more than twelve feet deep. It exhibited the Lower Greensand reposing unconformably on Kimmeridge clay. The following is a detail of the stratification:—

1. Kimmeridge clay, having at the top masses of imperfect limestone, or septaria, bored by the Lithodomus shells of the lower greensand; the shells themselves being preserved *in situ*, and the holes filled up with the ferruginous sand.
2. Masses of imperfect, gravelly sandstone and sand, not very ferruginous, containing pebbles of quartz, &c. and numerous fossils.
3. Dark green and brown sands.
4. Iron sandstone, with fossils.
5. Yellowish sand.
6. Iron sandstone.
7. Sands, &c.

The whole surmounted with a patch of yellow, brashy clay of a few acres in extent.

Section from Seend to Devizes.



a. Kimmeridge clay.
b. Lower greensand, exposed in the cutting of the road at Seend.
c. Lower greensand.
d. Gault, 80 feet.
e. Upper greensand, 90 feet.

The Kimmeridge clay has the usual appearances of that stratum, and contains many specimens of *Ostrea deltoidea*, Sow., *Ammonites*, &c.

The fossils of the lower greensand of this spot are mostly identical with those from the Farringdon beds. The Farringdon sponges, however, have not hitherto been found in Wiltshire. The following is a list of some of the organic remains, and I would direct particular attention to the *Terebratulæ*, as among them will be found some characteristic and important forms.

Ammonites Nutfieldiensis, *Sow.*
Emarginula Neocomiensis, *d'Orb.*
Propilidium, sp.
Patella, sp.
Rostellaria, 2 sp.
Trochus, 2 sp.
Terebratula Menardi, *Lamk.*
—— nuciformis, *Sow.*
—— oblonga, *Sow.*
—— tamarindus, *Sow.*
—— latissima, *Sow.*
—— Gibbsiana, *Sow.*
—— sella ?, *Sow.*
Terebratula Rœmeri, *d'Arch.*
—— elongata ?, *Brongn.*
Opis Neocomiensis, *d'Orb.*
Pecten, 3 sp.
Modiola, 2 sp.
Arca, sp.
Lima, sp.
Corbula, sp.
Nucula, sp.
Asterias.
Diadema.
Several small corals.

In the lower beds of the sand, rolled fossils and bouldered masses of rock derived from the Kimmeridge clay are abundant.

Some of the ironstone is very ferruginous, so much so as to have been formerly smelted, and masses of scoriæ from the ancient iron-works may be picked up in the neighbouring fields.

The similarity of the organic remains, the mineralogical character, the position, and the general resemblance of the Devizes beds to those at Farringdon, go far, I conceive, to establish the identity of these interesting deposits; and a step has thus been taken towards giving "a local habitation and a name" to the remarkable strata at Farringdon, which have so long been the subject of controversy.

It would appear that both occupy a low position in the Lower Greensand series. It will, however, require a re-examination of the fossils (of which I have obtained a large number) in order to confirm these views.

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2. *On the* Age *and* Position *of the* Fossiliferous Sands *and* Gravels *of* Farringdon. By Robert A. C. Austen, Esq., F.R.S. G.S.

The object of the following communication is to give an account of a short geological excursion through parts of the counties of Berkshire and Wiltshire, by several members of this Society. The party consisted of Prof. E. Forbes, Mr. Sharpe, Mr. Prestwich, Mr. Tylor, and the author of this memoir; they were joined for the first day by Mr. Cunnington of Devizes, and they again had the advantage of that gentleman's knowledge of detail in their visit to his neighbourhood and Calne.

I propose to confine the account to the localities and sections

actually visited: the line of country was selected by Mr. Prestwich, and it may be as well to state briefly in the outset, the points of geological interest which mainly influenced the choice.

Those who are acquainted with the memoir of Dr. Fitton on *that portion* of the cretaceous series which occurs *in this country* below the chalk, are aware that the author clearly establishes that the several deposits of upper greensand, gault, and lower greensand are clearly distinguished, and developed in great thickness along the S.W. coast of the Isle of Wight. Subsequent observers, by greatly extending the knowledge we had of the lowest cretaceous fauna of this region, and determining the range of the various forms, have rendered it necessary that the base of this series should be everywhere re-surveyed. From the Isle of Wight westwards, the next section of the beds below the chalk is that presented at Swanage Bay, being thirty miles due west of the former: the differences which these two sections present are briefly these. The Wealden sands of Swanage are vastly thicker than in the Isle of Wight; the clays which surmount the sands in the Isle of Wight are on the other hand greatly thicker than those of Punfield, which are reduced to a few feet, but in which *Cyclades* and *Paludinæ* are so abundant that there can arise no question as to the extent to be assigned to them.

The very remarkable fact established by the Swanage Bay section is, that in an interval of thirty miles, the lower greensand, as exhibited at Atherfield, should almost or entirely have disappeared: beds which are the mud deposits of a freshwater lake are brought within a few feet of the sea mud, known as gault, and which here, though the same fossil forms mark it, has lost much of its dimensions, as compared with its extent in the Isle of Wight.

The strata of the cretaceous beds at Swanage are inclined at a very high angle; and the comment which the author of this communication would make upon Dr. Fitton's representation of the cretaceous series, as it occurs at this place, is, that the admeasurements of the beds are all greatly in excess, and that the lower greensand is not represented there at all.

In his representation of the cretaceous series, as exhibited in the cliffs of the west of the Isle of Purbeck, Dr. Fitton very correctly omits the lower greensand: as we proceed inland, it seems in like manner to be altogether wanting as far as the Vale of Wardour; at this place Dr. Fitton hardly ventures to introduce it, nor does his section or list of fossils from Warminster indicate its presence there.

The lower greensand, as a distinct division, is not expressly stated to occur until we reach North Wilts; it is introduced in sections Nos. 15 and 16 of Dr. Fitton's memoir *, and a list of fossils is given at p. 268; but, with the exception of a section through Swindon, Dr. Fitton does not profess to describe the succession of beds in detail, until he reaches Oxford.

In this way, and avoiding the field of others' inquiries, we seemed to have open to us a well-defined line of unexamined country; and our

* Geol. Trans. vol. iv. part 2. 2nd Series.

object was to make good the interval between North Wilts and the country where Dr. Fitton states that he resumed his observations (p. 270). What seemed to render this district more peculiarly interesting, was the circumstance that it included the beds at Farringdon, so well known from their fossils, as far back as the catalogue of Llwyd [1759]; described by Dr. Fitton as "outlying masses of lower greensand," and considered by him to be especially deserving of notice (p. 271); also that published lists afforded indications of fossil forms peculiar to this portion of the cretaceous series, and limited to a few localities, and which seemed to present a wide departure from the ordinary conditions which influenced the lower cretaceous deposits; such as the numerous and perfect *Amorphozoa* at Farringdon, several forms of *Terebratula* to be noticed in the sequel, and *Diceras Lonsdalei*, Sow.

In the present state of our information, the district we proposed to examine included all the localities at which the reputed beds of lower greensand were reported as fossiliferous; whilst the lists of the fossils from the several places contained such an apparent admixture of the forms of distinct geological epochs, as to make it an interesting inquiry how far the oolitic blended with the cretaceous fauna even in this country.

§ 1. Farringdon.

We commenced our observations at Farringdon, following the indications contained in the 'Geology of England,' that at that place "are two summits of ironsand, one on the east of the town, marked by a conspicuous clump of firs, the other on the south-west" (p. 190). Farringdon Clump is a conical mass, crossed on its south slope by the high-road from the railway station; on the upper side of the road is a good section of the beds which compose the hill at this level, consisting of pale yellow stratified sands; at a rather lower level, a brick-yard has been established on beds of clay, and the sands which immediately overlie the clay contain subordinate concretionary sandstones. No pits are worked in any portion of the hill above the road; but from the character of the cultivated ground, it is evidently wholly composed of sand. Crossing over the hill, the sands descend to the highway road which passes it on the north, and are followed by a breadth of cultivated clay land resting on coral rag, which forms a low ridge above the valley of Oxford clay. Some large pits are worked in the calcareous coral rag, just at the entrance of the town of Farringdon, on the east, and these are interesting from the alternations which the upper portion of the coralline strata presents with bands of blue clay, and from the disturbances which seem to have repeatedly taken place—indicating somewhat more than ordinary submarine action, previous to the establishment of those conditions which favoured the deposition of the superincumbent clays.

It is mainly from the manner in which the lower portion of this mass of clay is associated with the top of the coral rag—one so commonly occurring with respect to the different component mineral groups of all great geological formations—that we are disposed to

consider the clay-beds beneath the Farringdon Clump sands as belonging to the oolitic period, or of the age of the Kimmeridge clay.

The brick-earth beds on the south side of Farringdon Clump would, from their difference of level, constitute the upper portion of this clay, and a section through the hill from north to south would give such a sequence as that represented in the Section.

The upper sands of Farringdon Clump did not afford us any fossils.

The next line of section we proposed to take was across the other eminence of ironsand to the south-west of the town. Following the road to Lechlade, the coral rag is continued as far as the 71st milestone, ending where the road slopes down to the low ground of Oxford clay. We then struck across by Eaton-woods and Oak-wood, both on Oxford clay, towards Badbury Hill: ascending it on the north-west, the coral rag was seen to show itself as a belt along the hill side—surmounted by a retentive stratum, which, though not exposed, would represent the clay of Farringdon Clump; the change to the higher sands being indicated by the limits of the waste ground, and the growth of furze. The upper sands of Badbury Hill have evidently suffered diminution, as blocks and fragments of stone containing fossils are abundantly strewed over the surface.

The road from Coleshill to Farringdon crosses this hill, and affords a good section from west to east; the lower part corresponds with that east of Farringdon. Mr. Sharpe and Mr. Prestwich ascertained the presence and thickness of the Kimmeridge clay surmounting the coral rag. The sands of this hill have apparently a much greater thickness than on Farringdon Clump, as we might expect from the greater extent of the mass. A large sand-pit occurs by the roadside on its west slope. The conditions of deposition which the beds indicate at this place are such as commonly occur in the lower greensand—the mass is stratified, and the beds have an irregular, and often waved diagonal arrangement; the sand is sharp, and contains fragments of comminuted shells and corals (*Milleporæ*, *Celleporæ*). Higher up are compact bands with pebbles, the shells, chiefly valves of *Exogyra* and *Terebratula*, being more perfect and more abundant. The tabular summit of the hill consists of layers of sandstone, used for the roads, in which organic remains are scarce; we found in these a few specimens of fossil wood, and the leaflet of a fern.

Taking the slope of the whole mass of sands and sandstones of Badbury Hill from that of the compact beds in the road section, it would seem to be south-easterly.

The sands follow the slope of the ground towards Great Coxwell, their termination upon the mass of clay being indicated by a line of springy ground; the grazing lands about this place are on these subjacent clays. Near Little Coxwell the sands reappear, and about half a mile north of the village is a great pit, the first we visited, of the celebrated fossiliferous gravel of Farringdon.

This pit is of great dimensions, and presents vertical sections, 20 feet deep, of beds of coarse sand and subangular pebbles, mixed up with which is a vast accumulation of organic remains: the dip of the mass is about 4° to 5° east, and the total thickness exhibited from west to

east may be safely estimated at 40 feet. There is another pit at a short distance on the north*, and we subsequently visited a third; all of these occupy low ground with respect to Farringdon Clump and Badbury Hill; and taken by itself, the relation of the mass to any of the formations of the district is very obscure. Apart from the organic remains it might be taken for a mass of stratified drift gravel: a geologist who should be guided by such characters as those of general aspect, mineral composition, and mode of accumulation, and who finding himself in one of these pits, was required to determine the age of the deposit, might most excusably suppose himself to be in the Crag district of Suffolk: in both accumulations there is a like condition of the mineral materials, a like arrangement of the component beds, and a like proportion, as well as condition, of the included animal remains. In these latter respects the Farringdon beds are of great interest, as they present to us the only instance now remaining, in any part of Great Britain, of a bank of subangular sea-gravel of the secondary period. As compared with the mass of the Crag generally, its condition much more nearly approaches that indicated by the red; it is however less coarse; and though the remains of animal structures are in the aggregate equally abundant, the poverty of the Farringdon fauna in species, as compared with any Crag pit, is very remarkable. I am not aware that the collection formed by the whole of our party contained, with the exceptions to be noticed, the shell of a single bivalve or gasteropod mollusk.

Terebratulæ are abundant; their valves mostly united, and but little injured, considering the coarse materials in which they occur; the small urchins (*Diadema, Salenia*) are also uninjured. The sponges retain their natural forms of growth, with their external characters as distinctly preserved as in recent specimens: it is difficult to determine whether they always occur in their true positions, but most of the larger pebbles exhibit traces that these bodies have fixed themselves to them, as also have the oysters. On the whole we may safely assume that the various forms lived at the spot at which we now find them—an association not at all at variance with that condition of sea-bed which a pebble-bank implies. If in judging of the depth of water from the sponges which lived about the Farringdon gravel beds, we are guided by the recent and allied forms, such as *Halichondria palmata, Tragos infundibuliforme,* and *T. ventilabrum,* we should suppose it to have been about 40 fathoms, and with strong currents.

The mineral character of the pebbles which compose this gravel suggests considerations of much interest in the history and source of origin of the materials which compose the secondary deposits of this country. The pebbles, as a mass, have been derived from altered sedimentary strata—such as shales converted into flinty slates or hornstone, and which must also have contained great subordinate veins of

* This pit was examined by Mr. Sharpe and myself at our second visit. We ascertained here the fact, that the gravel beds rested on the Kimmeridge clay, and with this clue we found that such was also the case with the gravel of the large pit.

quartz rock: waterworn crystals of felspar may also be detected, indicating the loose structure of the mass of felspathic granite, or porphyry, from which they were separated. The mineralogical character of the coast-line, whence the materials of the Farringdon gravel were derived, is thus clearly indicated, and is one which must necessarily, from the well-known distribution of masses of crystalline rocks, have existed at some considerable distance from the spot to which the gravel has been transported: in addition to these older fragments, but much more sparingly, are fragments of secondary calcareous rocks, much eaten out by perforating animals.

The mass of gravel, wherever seen, is so identical in its arrangement and composition that it will be unnecessary to enter into any detailed description of the several pits in which it is exhibited. In a large quarry due south of Farringdon, on the road leading to Furze Hills, the beds rise gently to the east, which would give a trough-shaped arrangement to the gravel beds as a mass: in this pit the beds are much faulted.

The coral rag is quarried at no great distance to the north, and from the alternations of clay we may conclude that the beds there exposed are the uppermost portions of the mass; the slope of these beds would carry them below the gravels, but from the level and cultivated surface of the ground, we have no clue as to what strata fill up the interval. The ground rises gently to the tract known as Cole's Pits—an area presenting numerous circular excavations, some 20 feet deep, in a mass of loose sand: the whole surface of the hill seems to have been worked over. The antiquarian* has claimed the spot as showing the excavated habitations of some early people; whilst the Farringdon tradition points it out as the site of the castle of "King Cole," whose memory is preserved in a well-known fragment of popular poetry; but geology can countenance no fictions except its own, and Cole's Pits are evidently the remains of the open workings for the ironstone underlying the mass of sand: the thickness of the sands of Furze Hills must be very considerable. A retentive clay comes out beneath their mass on the east, and in the village of Fernham the compact gravel beds are again exhibited: we did not proceed further, but returned to Farringdon by the west side of the Furze Hills. Mr. Sharpe, Mr. Prestwich, and Mr. Tylor examined the underlying clays, used for brick-making at Ringtail Farm on the west, and Prof. Forbes collected from a band of fossiliferous ironstone and conglomerate which occurs beneath the upper sands.

The distance from Fernham to the escarpment of the chalk is three miles, and so far the Farringdon sands and gravels had been seen only as independent beds superior to a mass of clay above the coral rag. The country beside the sands of Fernham and Alfred's Hill is a low tract of clay,—a portion of this must evidently be

* The pits are 273 in number. Barrington supposes this to have been "a considerable city of the Britons, and, at five souls in a pit, to have contained 1400 inhabitants."—Archæol. v. 7.

considered as Kimmeridge; and the only way in which we could construct a section which should show the relations of the several groups up to the chalk, was by supposing that a fault existed at the base of that escarpment by which the Kimmeridge clay and gault were brought to the same level. The solution of this was one of the points we proposed for our second day's work. To enable us to embrace a larger area, our party separated; Prof. Forbes, Mr. Prestwich, and Mr. Tylor to examine some reputed quarries of Portland stone near Stamford, and then to make a transverse section to the chalk; Mr. Sharpe and Mr. Austen to take up the section from Fernham, and carry it on to the escarpment of the White Horse.

Quitting the horizontal platform of coral rag by Bowling Green Farm, we struck across the grass-lands by Wichwood and Little Medbury Farms, situated on dark blue clay; the sands and masses of the compact gravel reappeared a little south of the road from Fernham to Shillingford, thus resting on the clays. The Baulking cutting is through a ridge of blue clay, of which the inclination is east, as marked by one or two hard pyritous bands. South of the Railway there is a tract of furze land, where the clay seems to present a passage upwards into laminated sands. Uffington is on the blue clay, in which on the south of the village is a brick and tile yard, the beds consisting of a tenacious blue clay, and requiring an admixture of sand, which is brought from Alfred's Hill. From Uffington to the chalk there is a level of nearly a mile, affording no section, but the soil consisting of clay. With the rise of the ground the gault was distinctly marked, succeeded by upper greensand, forming a distinct under-terrace, to the lower chalk. Having traced the sands and gravel beds as far as the ridge overlooking the stream north of Gaun's Bridge, we thought it possible that they might pass beneath the clays of the Baulking cutting, for in the total absence of fossils, as far as we were able to ascertain, this mass of clay might be either that of Kimmeridge or the gault.

From Uffington we went to the summit of the chalk escarpment at Uffington Camp, followed the old Ridge-road for a short way, turned down to Compton Beauchamp, and followed the under-terrace of upper greensand as far as Ashbury, and then crossed the valley by North Mill and Stainswich Farms to Shrivenham: the whole of the interval between the base of the chalk and the Canal is a flat clay valley. The coral rag rises close to the village, at the back of Lord Barrington's stables, where it is quarried.

We rejoined Prof. Forbes, Mr. Prestwich, and Mr. Tylor at Shrivenham; they had visited the reputed Portland quarries at Stamford, and ascertained that they belonged to the coral rag, and then, following the line of the superincumbent Kimmeridge clay, had traced it passing beneath the sands of Alfred's Hill: the determination of this point was a most interesting one in the relations of the Farringdon deposits, and one which Mr. Sharpe and myself had been unable to ascertain by Gaun's Bridge. From this too it was clear that the expanse of blue clay, of the line of the Great Western Railway, in which are the Baulking and other cuttings, belongs entirely to the

Kimmeridge, and that it is this portion of the oolite series which here underlies the gault.

The sands at Alfred's Hill were carefully examined by Mr. Sharpe and myself at a subsequent visit.

From Shrivenham the party proceeded together in the direction of Bourton. Between the Canal and the Railway is a large brick-field worked in a strong blue clay, and which from its relative position with the coral rag we considered as Kimmeridge. Beyond the Railway the ground rises; the lower part of Bourton Hill consists of the same blue clay, but towards the upper part of the village a mass of thin-bedded freestone sets on. The whole of the summit of the hill is so composed, and on the road leading S.E. a large quarry exposes more calcareous and thicker beds. The fossils from these beds were few, and only internal casts: *Trigonia incurva*? Sow., *Cardium dissimile*, Sow., and a large *Pleurotomaria*.

It is stated in the 'Outlines of the Geology of England,' p. 181, "that in the interval from Abingdon to Seend, the Portland beds, reposing on Kimmeridge clay, are only seen at one point, namely at Swindon;" and Dr. Fitton does not notice it at any place between those here indicated. There can be no question, however, that the beds which cap the hill at Bourton belong to the Portland oolite.

From Bourton to the foot of the chalk escarpment is an interval of about two miles, in which there is no opportunity of observing the nature of the beds, but which is evidently a clay, and therefore most probably an extension of that of the lower part of Bourton Hill. The gault with the overlying upper greensand are seen in considerable thickness at the foot of the chalk escarpment at Little Hinton; thence our route lay along the under range of upper greensand through Wanborough to Swindon.

In applying the names of Gault and Upper Greensand to the beds which underlie the chalk along the line here described, it is not intended to convey the notion that any separation can be traced between two well-defined groups, or that even any true sandy beds occur; indeed there is no name in the whole series of geological formations so purely conventional as that of Upper Greensand;—what is meant is, that the beds below the chalk here represent the upper greensand and gault of those parts of the cretaceous area where those groups are distinct. The form this part of the series here takes, from below upwards, is that of a dark blue argillaceous mass, passing by a gradual increase of sandy particles into a dark argillaceous sand; and by the substitution of calcareous matter for the argillaceous, there is a slow passage into the lower chalk.

There are one or two features connected with the chalk escarpment which may yet deserve notice. The highest point, Uffington Camp, appears to rise no higher in the series than the chalk without flints: the steep angle of the slope of the escarpment, its very sinuous outline whereby the numerous picturesque coombes are produced, the great volumes of water which burst out at its base, are points of much interest, the latter especially. Great blocks of flint-breccia and grey-wether-sandstone are scattered, not only over the table surface of the

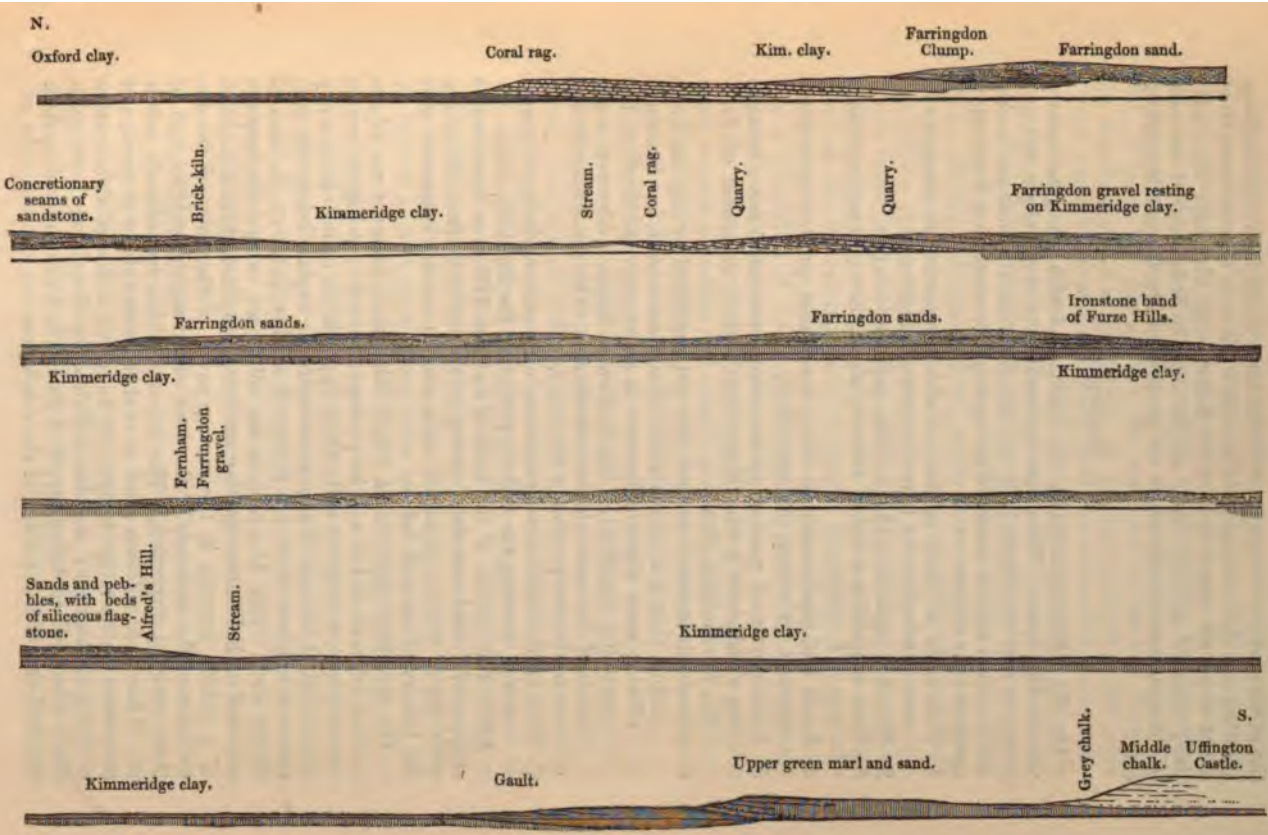
chalk, but over the under-terrace of upper greensand, as about Hinton and Wanborough, and considerably in advance of the chalk, as over the area of Kimmeridge clay and coral rag. Many of these blocks are of great dimensions, and have most probably sunk down vertically to their present positions from their places in the eocene deposits, by the removal of the intervening beds by denudation.

Our time would not allow of detailed examination of the Portland beds of Bourton, I therefore subsequently visited the place again; first alone, and again in company with Mr. Sharpe. The order of the beds can be well traced on the east of the hill, and from above downwards is as follows:—

1. Stratified earthy oolite. *Ammonites*, casts of *Trigoniæ*. 8 feet?
2. Buff-coloured sands, with bands of pale yellow sand. No fossils. 12 feet.
3. Flat-bedded, white, oolitic sand. No fossils. 8 feet.
4. Rubbly oolite. Large *Pleurotomariæ*. 1 foot.
5. Thick-bedded fossiliferous band. 3 feet.
6. *Ostrea* and *Perna* bed.
7. Pebbles in calcareous beds. Fossils numerous. 10 feet.
8. Fine sands. 7 feet?
9. Kimmeridge clay.

The bed No. 7 escaped our observation at our first visit. My attention was called to it by the numerous and large blocks of conglomerate which are to be seen built into all the walls of the village of Bourton: the lower levels of the quarry from whence they are taken being filled with water, the succession of the beds cannot at all times be observed there below the band of *Ostrea* and *Perna*, No. 6. They are, however, to be seen *in situ* in the road section, and with their underlying sands confirm the account which the quarryman gave me of the lowest beds. The pebbles consist of subangular fragments of white, transparent, and granular quartz, such as fine-grained sandstones are seen to become in proximity with intrusive crystalline rocks. Much more abundantly there occur black pebbles of hornstone or lydian, which contrast forcibly with the white calcareous cement in which they are imbedded. In the conglomerate beds I met with the internal cast of a bivalve shell (*Cardium*), the material being identical with that of the mass of black pebbles, showing that the strata which have supplied this portion of the beds were altered sedimentary deposits, at the age and precise locality of which we may therefore some day be enabled to arrive. The *Pernæ* and *Ostreæ* form a band, as they do in the Swindon quarry; and above occur the principal fossiliferous beds, No. 5. The large *Pleurotomariæ* also form a distinct band. No fossils that I could discover occur throughout the 20 feet of oolitic and siliceous sands, but they reappear in the uppermost beds, consisting of casts of *Trigoniæ* with *Ammonites giganteus*, Sow., and *A. biplex*, Sow., in great numbers.

The series of Portland beds as here described are nearly horizontal, and the blue Kimmeridge clay which is seen passing beneath the sands and oolite on the north side of the hill, comes out from beneath them on the south at a somewhat higher level than that of


N.
Oxford clay.
Coral rag.
Kim. clay.
Farringdon Clump.
Farringdon sand.
Concretionary seams of sandstone.
Brick-kiln.
Kimmeridge clay.
Stream.
Coral rag.
Quarry.
Quarry.
Farringdon gravel resting on Kimmeridge clay.
Farringdon sands.
Farringdon sands.
Ironstone band of Furze Hills.
Kimmeridge clay.
Kimmeridge clay.
Fernham.
Farringdon gravel.
Sands and pebbles, with beds of siliceous flagstone.
Alfred's Hill.
Stream.
Kimmeridge clay.
S.
Grey chalk.
Middle chalk.
Uffington Castle.
Upper green marl and sand.
Kimmeridge clay.
Gault.

the surface which it occupies over the tract which intervenes between Bourton and the escarpment of the chalk : it is an isolated mass, from about which the upper beds of the Kimmeridge clay have been partially removed on every side ; nor do any like beds occur at the base of the cretaceous series, where the gault rests directly on Kimmeridge clay.

§ 2. Swindon.

On the following morning we commenced with the great quarry west of the town. The mass dips away at a small angle east and south, so that the lowest beds are exhibited on the west and north. At the north-eastern corner of the quarry the succession from below upwards is as follows :—

1. Thin seam of black pebbles, of which a portion is always to be seen attached to the lowest masses of sandstone.
2. Stratified sandstone, thin-bedded, pale blue : 5 feet.
3. Clay, containing a bed of *Ostrea falcata*, Sow., *Perna quadrata*, Sow. : 1–2 feet.
4. Sands and sandstones, 25 feet ; the lowest portion most fossiliferous. *Cardium dissimile*, Sow.
5. Calcareous sand, passing up into pure limestone, 5 feet ; containing a bed about 1 foot thick almost entirely composed of *Terebra Portlandica*, Sow.
6. Above this marine limestone, but not separated by any line more distinct than is usual in stratified limestone masses, is a limestone offering some slight differences in appearance and fracture, but containing apparently only freshwater forms. Above this are bands of clays and calcareous sandstones. The whole constituting the freshwater portion of the series.
7. Thin-bedded calcareous sandstones, with marine shells, in a mass of sand, forming the highest portion of the Portland series.

Above the surface of the beds of Swindon Hill is a considerable capping of drifted materials, resting on an uneven surface, containing materials of various geological ages, and in no way connected with the history of the beds below.

The geological phænomena which this quarry presents are of exceeding interest, and it will be perhaps the most intelligible course we can adopt, in order to make them appreciable, if, instead of a dry mineralogical account of admeasurements, we explain briefly the successive conditions which are indicated at this spot, over an area of fifteen acres. 1st. At a place in the oolitic sea, where the deep-sea mud-bed of the Kimmeridge clay was being deposited, there is evidence of a sudden increase in the moving power of the water, of the disturbance of the materials of the zone of subangular pebbles, and of their outward dispersion. The deposits which immediately follow are of fine clean siliceous sand, or at times with a slight proportion of calcareous matter : the change here indicated is that of a diminution of depth at this spot ; or, what will describe the change more accurately (the sea-level being supposed uniform), a rise proceeding from the land-side of this portion of the oolitic sea.

Dr. Fitton notices a Portland sand as a separable group from the Portland stone at this place; and as it appears to us, most unnecessarily: the whole of the lower portion of the mass which succeeds the Kimmeridge clay is arenaceous, of which the building-stone constitutes subordinate bands. After an accumulation of about five feet of sands had taken place, the conditions of sea-bed favoured the development of a great bank of the *Ostrea falcata*, Sow., and *Perna quadrata*, Sow.; the bed is from one to two feet thick, composed to a great extent by these two forms alone, with fine sedimentary matter in layers. Sands, now mostly passed to the condition of sandstone, succeeded, and which for the first few feet are remarkably rich in the usual fossils of the Portland (*Trigonia clavellata*, Park., *Cardium dissimile*, Sow., which here attains a great size). Throughout the remaining portion of the sands and sandstones fossil remains are comparatively scarce, with the exception of *Ammonites*, which occur irregularly. The grain or line of deposition of the building-stone masses accords with the bedding, whilst the arrangement of the intervening sands is mostly diagonal. The particles composing the stone are finer than those of the sands, and they contain a proportion of lime; the difference is due in the first instance to a varying moving power of the water.

In the calcareous beds of the Swindon Portland, organic remains again become abundant, and certain new forms predominate, such as the *Terebra Portlandica*, Sow., which alone forms a band of some thickness near the base of the pure limestone portion.

The limestone mass, when its lower portion is compared with its upper, presents a slight mineral change, which hardly admits of being described, but which is perceptible on the spot—and this change is found to correspond with the condition of the mass of water under which it was deposited—the lowest portion is marine, the forms in the upper are those of fresh water. The only feature which at all indicates a change of condition of the water is the gradual decrease of the forms so abundant in the lower portion of the limestone; there is no passage through brackish water forms, nor any break to show an interval of time, or a change from sea-bed to that of a lake, but simply such a change as would be the result of the influx of a mass of fresh water into the oolitic sea, bringing with it its own peculiar forms, and thus rendering a given area objectionable to marine ones. The diminished size of the *Cardium* may perhaps be taken as an indication of such a change in the condition of the water, and the small *Ostreæ* which occur within the mass containing *Cyclas*? and *Cypris* would clearly show that the calcareous beds still belonged to the area of the oolitic sea.

At a time subsequent to the first indications of this change of condition the limestone mass has been greatly disturbed, great blocks have been detached, and rolled about on the surface of the mass, and these are often eaten out by some excavating animal, and we must consider these fragmentary beds as having been produced by the ordinary action of the sea, when the mass had been brought up to the condition of a submerged reef, and within the reach of wave-ac-

tion. The higher portions of this part of the series consist of bands of clay, with carbonaceous matter and occasional partings of sandy and calcareous materials, now passed to the state of loose rubbly stone. For a considerable thickness the beds indicate times of tranquil deposition, of the occasional disturbances of such surface, of no great depth of water, and the proximity of some area of land.

If the conditions recorded in the Swindon quarry are to be derived from its western side alone, it would seem as if this fragmentary and disturbed portion constituted the close of the series of changes, which followed in the long uniform period indicated by the Kimmeridge clay. The summit of Swindon Hill forms a tabular surface, and owing to the inclination of the beds, the denudation which has taken place at some period long subsequent, has proceeded to a lower portion of the series on the west to what it has on the east; and (with the exception of a capping of detritus, containing materials of all ages up to the grey-wether-sandstones) the fragmentary and disturbed beds form the highest part of the quarry; the like holds good along the north side of the quarry and part of the eastern, but with the dip of the beds south, these disturbed bands of clays and sands are seen to be surmounted by layers of tranquilly deposited sandstones in thin layers interstratified with sands, and in these the forms of the marine Portland reappear*.

We next examined a quarry about a mile from the town of Swindon, on the north of the road to Coate: the beds in which it is opened belong to the upper calcareous portion of the Portland, and present a like order in the occurrence of the fossil forms with that already described. The limestone mass seems to be surmounted with thin-bedded sandstone. About a quarter of a mile on the same road, but on the south side, is another large quarry: the beds here dip to the north, which would take them beneath those of the quarry just noticed. The beds are sands and sandstones, which agree very exactly with those of the lower portion of the great quarry close to the town. At Broom Hall the lowest sands and sandstones are seen resting on the Kimmeridge clay, with a band of black subangular pebbles at the line of junction, and incorporated with the lower layers of stone. The last place in this direction at which the Portland beds are worked is on the east side of the reservoir: here also they belong to the lowest part of the series, resting on Kimmeridge clay, and containing the like admixture of lydian-stone pebbles. The ferruginous sands which surmount the compact sandstones, on the level of Day-house Farm, contain beautifully preserved specimens of *Trigonia gibbosa*, Sow. The thin Kimmeridge clay, which emerges from beneath this mass of Portland, is continued to the rise of the

* Mr. Brodie has given an account of what he designates as the "Purbeck strata" at Swindon (Geol. Journ. vol. iii. p. 53). His section is taken at the western end of the quarry, and represents a thickness of 13 feet. The description given by M. Cornuel of the upper jurassic strata of Vassy agrees well with the series of conditions to be observed at Swindon, the "Oolite vacuolaire" representing mineralogically as well as in its *Cyrenæ*, *Mytili*, and *Melaniæ*, the fluvio-marine strata of the top of the Portland.

cretaceous escarpment. We were unable to confirm the representation of Dr. Fitton, that the lower greensand occurs at the top of Swindon Hill (p. 265). Day-house Farm is also described as affording the Purbeck, Hastings, and Wealden beds in superposition on the Portland, but we have shown that it is the *lower* portion of the Portland only which occurs at that place: the sands which Dr. Fitton has represented as lower greensand at this place* (the mineralogical resemblance having probably induced the view), belong to the middle portion of the Portland series, as indicated by *Trigonia gibbosa*, Sow.

The principal point of interest presented by the section along the east side of the great quarry at Swindon, and which, if observed here or elsewhere, has been useless so far as any inference from it is concerned, is the fact that the period which is marked by considerable disturbance, by irregular deposits, carbonaceous materials, and freshwater forms, is overlaid by tranquilly deposited beds of marine sand and sandstone of the Portland series. Dr. Fitton appears to have overlooked the fluvio-marine conditions indicated at the Swindon pits, but it is this higher portion of the Portland series which I imagine he notices at p. 265, and describes as white calciferous sands, with concretions in which are Portland fossils, and occurring at the top of Swindon Hill, and occupying the position of the beds at Dinton, full of *Ostreæ* and *Mytili*, which surmount the alternating series of clays, limestones, and fossil sandstones containing *Cyclas* and *Cypris*.

I do not propose to enter now on any speculation as to the physical features of the Wealden, particularly as I propose to make the whole body of the evidence we possess as to the nature and extent of its area the subject of a distinct communication. The conditions indicated by the series of beds at Swindon, containing freshwater forms, were at no time those of a closed or land-locked area of fresh water, but rather the conditions of a sea contiguous to a body of fresh water, and into which masses of fresh water were discharged. Neither is it necessary here to ascertain the portion of the Wealden group with which the Swindon beds are synchronous; that they are the geological equivalents of some portion is sufficiently clear, and the point which the Swindon section clearly establishes is, that the Wealden is not, as has hitherto been represented, a freshwater accumulation of an area of dry land subsequent to the oolitic period, *but was contemporaneous with the Portland, and perhaps even with older portions of the oolitic series.*

The other points which suggest themselves as deserving of notice arise out of a comparison of the two masses of Portland strata at Bourton and Swindon,—the distance which separates them is from six to seven miles. In the lower portions of both occur beds of subangular pebbles, which mineralogically are identical, and in all probability derived from the same source. That the dispersion of these pebbles was not due to some momentary disturbance is clear from the thickness of the beds through which the pebbles range at

* *Loc. cit.* Section No. 17, pl. 10 *a*.

Bourton (10 ft.), a thickness which implies a vast lapse of time: conglomerate beds occurring in this way only indicate that the depth of this portion of the oolitic series, at this particular spot, was that of the zone along which subangular pebbles are drifted. The calcareous portions of the two masses do not differ to any extent worth noticing; and the yellow and buff fine-grained sands, which at Bourton surmount the calcareous oolitic sands, taken together, correspond in thickness with the main mass of sands and calcareous sandstones at Swindon, whilst the uppermost calcareous beds of Bourton would agree in position with the main portion of the limestone, the rest of the series having been removed from above the Bourton mass.

It will be seen from this that the Portland beds at Swindon and Bourton are isolated masses of considerable thickness and compact structure, resting on Kimmeridge clay. The surface of the oolite formation may have been eroded at various times, but the effect produced at one particular period is perfectly distinct from every other. No fact can be more certain than that the sea cannot transport sand and gravel across areas of impalpable deep sea mud, and there pile them up in detached conical masses. So that when we meet with such accumulations as those of Bourton and Swindon, we may feel assured that at some time they formed portions of continuous beds of such materials, and having an extent equal, at least, to the area over which the isolated patches now occur. The fact that these Swindon and Bourton masses of the Portland series rest on Kimmeridge clay, and that this same clay, at short distances, varying from half a mile to two miles in breadth, passes beneath the gault, *clearly shows that this particular denudation of the Portland had taken place before the earliest beds of the cretaceous series were deposited.*

§ 3. Devizes.

It will not be necessary to notice the beds of upper greensand which occur here, as they are well known from the forms which they supplied to the 'Mineral Conchology': they attain a great thickness, are well exhibited in several deep road sections, and are more uniformly arenaceous than at places to the eastward—a mineralogical change which becomes marked as the upper greensand ranges from east to west.

About halfway down the series of rocks at this place, beds of blue clay are exposed in a brick-yard, and which were long since described as "gault" by Mr. Lonsdale. The clay descends to the level of the water at the bridge, which would give it a thickness of about 40 feet: just beyond the bridge, beds of thin-bedded sandstone are exposed in the bank of the Canal, and like beds, together with ferruginous bands, were traversed in sinking a well at the residence of the engineer, close to the bridge: the ferruginous blocks were very fossiliferous, containing casts of a small *Nucula* in great abundance, *Arca*, *Cypricardia*, and *Emarginula*.

From the information we received from Mr. Cunnington, it would appear that the thickness of this bed of ironstone, sandstone, and

conglomerate must be very trifling, as it occupies only a narrow breadth of land in advance of the ridge of gault clay, and is quickly succeeded by the Kimmeridge clay.

At Rowde, and the other places at which we subsequently saw these beds on our way to Calne, they are evidently thicker; and in their general arrangement and composition closely resemble the more ferruginous portions of the Farringdon gravel beds, such as those of Fernham. At Stock-Orchard, near Calne, we again saw the ferruginous conglomerate resting on the surface of the Kimmeridge clay, and not having any great thickness or continuity, as the Kimmeridge clay had been reached through it, and emerged from beneath it in the south. It is this locality which afforded what is apparently a rare shell in this deposit—the *Diceras Lonsdalei*, Sow., figured amongst the illustrations to Dr. Fitton's memoir.

No one can reasonably doubt the geological identity of the ironsand and gravels of Devizes, Rowde, and Calne with those of Farringdon. The same specific forms of *Nucula*, *Opis*, *Emarginula*, and *Terebratula*, connect them one with another.

The ferruginous sands and gravels which we have thus identified as of one and the same geological level, on better evidence than was before possessed, are referred by Mr. Conybeare to his group of 'Ironsands,' an assemblage of deposits grouped together from the circumstance of presenting a large proportion of iron, and including the ironsands of the Weald, some of the ferruginous portions of the upper greensand, as well as the deposits here in question. The impropriety of classing these several masses together was apparent, when the freshwater origin of the ironsands of the Weald became established.

It will be seen by the sections, as well as from the account of the mode of occurrence of these several masses of ferruginous sands, that the line of the Devizes Canal and its vicinity is the only one along which they occur in an intermediate position between the gault and the Kimmeridge clay; and it was this circumstance I imagine which induced Mr. Lonsdale to refer them to the cretaceous series, whose views were adopted subsequently by Dr. Fitton. The superposition in this case will be presently considered, whilst the amount of fossil evidence, as exhibited in Dr. Fitton's paper, would hardly admit of the identification of the beds of Rowde and Lockswell Heath with the lower greensand.

Geologists who may be disposed to take Mr. Lonsdale's and Dr. Fitton's views respecting the cretaceous age of the ferruginous sands and gravels, or, as they had better henceforward be called, the "Farringdon beds," will naturally lay great stress on the Devizes section: what we have therefore to inquire is, the real value of this particular instance of superposition. It is by no means a necessary consequence, that an arenaceous deposit, because it occurs in an intermediate position between the gault and the Kimmeridge clay, should be of the age of the lower greensand: if this sand was the *only* geological link required to fill up the interval between the two formations, the inference might be allowed; whereas we know that a vast

lapse of time, hundreds of feet of sedimentary deposits, and altered conditions of the whole of the northern hemisphere, are recorded between those two periods.

When we employ the term "lower greensand," we mean only to designate deposits of sands and sandstones, occurring beneath a *portion* of the cretaceous series, and connected with that series, not by any specific identity of its organic forms, but by a certain general resemblance and aspect of its fauna, and by some of its forms being referable to the same divisions and subgeneric groups, as in its Fishes, Cephalopods, and Echinoderms.

The lower greensand is not everywhere co-extensive with the cretaceous series, and where it is wanting the series commences with the gault, the chloritic sands, or even with the lower chalk, as the case may be; but whenever the lower greensand does occur, its relation to the gault is invariable—it is beneath the gault*. It is not necessary that we should here enter on an inquiry as to what were the particular submarine conditions which caused the gault clays to overlap the lower greensand in the extension of the cretaceous series westwards; a process which, in turn, is repeated by the upper greensand with reference to the gault; but it is clear that so far as each of these divisions extended itself, it must have done so continuously. Such is not at all the condition of the masses of ironsand and gravel in question; the Farringdon beds, with a thickness perhaps of 100 feet, rest, as an isolated mass, upon the Kimmeridge clays: at a distance of two miles, the cretaceous series commences with the gault, also resting on Kimmeridge clay. The sands and gravels at Farringdon are thicker than at any other place at which we find them, and did they belong to the cretaceous series, as represented by Dr. Fitton, we surely ought to find some traces of them below the gault. The remarks which arose on the subject of the isolated condition of the masses of Portland, at Swindon and Bourton, apply with even greater force to the much thicker accumulations of Farringdon: as in that case, so here, we may feel assured that the beds at Farringdon, Calne, and Devizes, formed part of a continuous zone of deposits, *which must have been denuded and reduced to isolated patches before the period of the gault*. Unless we can believe that these separate masses severally had not at any time a greater horizontal extent than they have at present, they must have been reduced to their present dimensions before the gault could possibly have been deposited on beds of Kimmeridge clay; and if at Farringdon a long period of denudation and removal of materials separates the ironsands and gravels from the gault, we cannot suppose that they can possibly form together a continuous and ascending series of deposits at Devizes.

The position of the whole of the Farringdon mass on the Kimmeridge clay, and *its perfect independence of the cretaceous series*, are facts which rest on the evidence of sections respecting which there is no ambiguity whatever; and we may therefore feel assured that they were subjected to that process of denudation which abraded the

* See Dr. Fitton's Sections, *passim*.

surface of the oolitic sea-bed prior to the deposition of the gault over Oxfordshire, Berkshire, and Wilts.

There are other considerations which warrant the assertion that the superposition of the gault on the ironsands at Devizes is of no value whatever, in the shape of proof of the sequence and connexion of the two deposits.

The oolitic deposits in their range into the South of England gradually acquire a north and south direction, and this disposition dates back to a period before the cretaceous, inasmuch as this latter series in its extension westwards overlaps in turn *every member* of the oolites: the two series may be represented by two converging lines or bands, which at length meet; but the order of succession presented at such point of meeting can no more prove the continuity of the gault with the ironsands *as parts of one system of deposits*, than it can with any portion of the middle or lower oolites with which it afterwards comes in contact. The position of the gault on the Farringdon beds at Devizes is clearly transgressive, and can only show that the latter are not newer than the gault (or of the age of the crag), which for anything to be seen at Farringdon might be the case.

From what has been here stated, as to the composition and position of the Farringdon and equivalent beds, it will be easily concluded, by some, that they must be either Portland or lower greensand, and if not one, then certainly the other.

One very apparent defect in the geological investigations of the present day, is the disposition to adjust each successive addition of knowledge to a certain artificial scale of formations; and of this tendency geology must free itself, if it would arrive at the true nature of the physical changes with which it is concerned. The artificial scale of formations, which still figures in elementary treatises, more particularly with respect to secondary geology, represents an order of superposition, and lines of separation, which are both untrue, as well with respect to the mineral masses as the forms they contain—the result of the too hasty generalization of local phænomena. The Farringdon beds seem to present an instance of what some of the steps may be in the progress of change from one series of formations to another.

If the Farringdon beds were non-fossiliferous, we should arrive at their age by such considerations as these:—that they occur at, and are connected with, the top of the Kimmeridge clay, and that they never occur in any other position—in which respects they coincide with the Portland deposits; that the lower portions of both consist largely of conglomerates, composed of peculiar materials; that the upper part of the Portland contains indications of a contemporaneous area of fresh water, as apparently the ironsand does at Shotover; that their denudation was effected before the period of the gault. On these and other common features, each of which is the evidence of distinct physical changes and operations, the which could hardly have taken place in the like order at two distinct periods of time over the same spot, we should be warranted in considering the Farringdon beds the equivalents of the Portland. I will not however press this

view in the simple form in which it is here stated; what I would urge is the great importance, in a physical point of view, of the distinct *independence* of the Farringdon series of deposits, and their total separation from the cretaceous, *as parts of a consecutively deposited group*, by the intervention of a vast period of denudation.

The process of denudation of any mass of sedimentary deposits to a given depth is probably equally slow, or implies an equal space of time with that which was required for its accumulation; and it implies too a complete change in the relation of the mass of water (the same agent in both cases) to the sea-bed. No broader lines can possibly be drawn by which to separate masses of old sea-beds, than those which indicate so great an amount of physical change as this; and bearing always in mind that geology is nothing more than the physical geography of former periods, we must allow to such features a primary importance beyond that of the continuity or first appearance of certain specific organic forms: the changes in the suites of such forms, through a series of deposits, are nothing but the consequences of new conditions brought about by the ceaseless oscillations of the earth's surface.

Having established, on physical considerations, the complete separation existing between the Farringdon deposits and those of the nearest portions of the true cretaceous series, it remains for us to inquire into the amount of fossil forms which may serve to connect them. The fossiliferous localities of the Farringdon beds are Rowde, Seend, Calne, and Farringdon: the recorded species are to be found in the 'Mineral Conchology,' in the lists of the 'Geology of Conybeare and Phillips,' in those of Dr. Fitton, prepared by Mr. Lonsdale and Mr. Sowerby, and in Mr. Morris's Catalogue.

In the Table of Species a column is added for the "gault and upper greensand," for the purpose of comparison with a portion of the true cretaceous series of this country. The numerous physical considerations we have gone over will however preclude the possibility of the Farringdon sands being grouped with the gault, even did the two accumulations present some amount of agreement in their faunas; the gault, moreover, is not an independent formation, but merely the accumulation of a given condition of deep sea, synchronous as a whole with that portion of the cretaceous deposits which we call "upper greensand."

	Kimmeridge Clay.	Portland.	Ironsands and Gravels.	Neocomian.	Gault and Upper Greensand.	France.	Germany.
Ammonites dentatus	.....	.....	Rowde.				
—— Nutfieldiensis ..	.....	C. and Ph.	Rowde	.....	.....	.....	Hils, Neoc.
Astarte cuneata	.....	Tisbury, Garsington ..	.....	.....	Blackdown.		
Cardium dissimile ...	.....	Swindon; Portland; Purbeck, in Cap.	.....	L. greensand of Fitton			
—— striatulum	Dogger [Oolitic] ...	.....	Lockswell, Sow. & Lons.				
Cytherea parva	.....	Fitton, p. 230	.....	L. greensand of Fitton	Folkstone, Blackdown		
Diceras Lonsdalei ...	.....	.....	Calne, Rowde	.....	.....	Neoc. d'Orb.	
Gervillia aviculoides	[Oxford clay]	M. C. and Fitton.....	.....	Weald, Isle of Wight.	Lyme Regis, Blackdn.		[Neoc.
Panopæa plicata.....	.....	.....	Rowde [u.g.s.? Morris]	.....	.....	.....	Hils-Thon, L.
Pecten orbicularis ...	.....	Fitton, p. 281	.....	L. greensand of Fitton	Devizes	.....	Hils-Thon, L.
—— interstriatus ...	.....	.....	Lockswell	Weald, *passim.*			Neoc.
—— neocomiensis...	.....	.....	Lockswell	Weald, *passim.*			
Plagiostoma rigidum	Malton [Coral rag]...	Shotover	Lockswell.				
Serpula variabilis ...	.....	Fitton	.....	Kent, Fitton.			
Solarium conoideum	.....	M. C.	.....	.....	Folkstone, Blackdown		
Terebratula lata.....	.....	.....	Farringdon, Lockswell.				
—— nuciformis ...	.....	.....	Farringdon, Lockswell, Rowde.	Wealden, Neoc.	.....	Oolitic, d'Archiac	Hils, Neoc.
—— oblonga	.....	.....	Farringdon, Lockswell..	.....	.....	.....	Hils, Neoc.
—— truncata.....	.....	.....	Farringdon	.....	.....	.....	Oolitic, v. Buch
Turritella excavata...	... .	Fitton, Tisbury	.....	.....	Blackdown, Fitton ...	Perte du Rhone.	
Thracia depressa ...	Weymouth	Emmets Hill.					
Vermetus umbonatus							
Trigonia gibbosa ...	.....	*Passim*.....	Lockswell Heath.				
—— clavellata	Weymouth	Swindon, Bourton ...	.....	L. greensand of Kent and Weald, Fitton.			

In this list it is very probable, or even certain, that there exist many incorrect identifications, but we may also assume that as they were not arrived at with reference to any such views as those of the present communication, such errors would only partially affect the value of the list as a whole, with reference to the general considerations it seems to suggest.

What cannot fail to strike every geologist is, that so many competent observers should have recorded so many species as common to the upper portion of the oolites, and the lower of the cretaceous series.

Prof. Edward Forbes informs me that Sir Philip Egerton identified the remains of the fishes he collected at Farringdon to be, with one exception, oolitic forms.

In addition to the Farringdon beds, we have also in this country another group of strata, at Speeton, resting on the Kimmeridge clay, not continuous or co-extensive with the gault, and which also seems to present a like admixture of oolitic and cretaceous forms; and we shall also see that a like association is presented in the marine formation of Hils, and in the upper oolite of Boulogne.

Guided by the considerations set forth in the local description of the several deposits, but more particularly *by the unconformity which exists between the Farringdon beds and the great mass of the cretaceous series*; as well as, secondarily, by that *intermediate character in the general aspect of its fauna*, I would venture to suggest that we should abandon the present abrupt limits we have hitherto assigned to the oolitic and cretaceous series respectively, and that we should see in the beds in question traces of the deposits, and a record of the conditions, which may partially serve to connect them. In proposing such an arrangement, it fortunately will not be necessary to introduce any new name or system into the already overburdened nomenclature of geological classification; the conditions which the Farringdon deposits seem to establish come as proof and confirmation of the value of a division already introduced by continental geologists, on considerations of the distribution and range of fossil forms, and to which they have given the name of "Neocomian," but which has hardly been accepted in this country, partly from deference to the term "lower greensand," and partly from a restricted view, that the scale of British deposits is to serve as the type and measure of the geological changes of all time and all places. I shall therefore show as briefly as possible, that such a view is not only inconsistent with what we know of the subcretaceous group generally in its range across the European continent, but that the Farringdon deposits explain the nature and extent of the physical change which separates this group from the true consecutive cretaceous series, on the one hand, and how, on the other, it presents here the like order of connection with the oolitic series below, which it does elsewhere.

Physical changes, whether of elevation or depression of an oceanic area, produce different geological effects, according to the conditions of the several portions of such area in respect of depth: the depression of a portion of the deep sea deposits of a given period, so that

after such disturbance such area should still continue to belong to the deep-sea zone, would not necessarily be productive of any very distinct geological features, such as that of want of conformity; and the only evidence of such change might be in mineral character, or even in the colour of the deposit, as in the case between the upper marls of the new red sandstone series and the lower marls of the lias. In this instance the whole series, from one to the other, is presented in our own southern counties as a consecutive one, and it is only in places where the physical disturbance produced a very different set of conditions over given areas, that the long lapse of time and the succession of changes in animal life are recorded, which really separate the new red sandstone group from the liassic.

The change which separates our lower greensand from the gault, over the Wealden district, is viewed as merely a change of mineral character; but the transition is everywhere so abrupt*, as to signify that a vast amount of physico-geographical change marks the separation; and it is this feature of change which corresponds with the broader line of separation indicated at Farringdon between the gault and the beds next below it, and shows that the continuity of the two deposits is only apparent, or, in other words, that with reference to their physical conditions, they are independent groups. Nor is this independence less strongly marked with respect to the fossil fauna of the neocomian, as compared with that of the gault and upper greensand deposits†. This fact was clearly established as to the portion of the neocomian which occurs in the Isle of Wight, by the joint work of levels, and determination of species, of Prof. Edward Forbes and Mr. Ibbetson, and is asserted most broadly with reference to the neocomian of France by M. d'Orbigny; but whilst the upper part of the neocomian is thus dissevered from the gault, the line of separation does not seem to be equally broadly drawn between its lower beds and the oolites. In Switzerland, as at Villengin, and along the course of the Leyne, whence the type of the "lower neocomian" was first taken, there appears to be a perfect continuity from the group of strata representing the Portland and Kimmeridge beds into those containing *Spatangus retusus*, Lamk. We have already seen the extent to which very competent observers in this country have traced out an agreement between the oolitic and neocomian forms. Prof. Phillips speaks decisively as to the mixture of Kimmeridge and cretaceous species in the beds of Speeton and Knapton; and at the Meeting of the French Geologists at Boulogne, certain reputed cretaceous forms are stated to have been found in the Portland beds, such as *Corbis corrugata*‡, Sow. sp.

* In point of fact, the gault here has been deposited on an uneven surface of lower greensand.

† Of the molluscous fauna of the so-called lower greensand of the S.E. of England, not a single species passes up into the gault.

‡ Nor is this the only locality where the reputed lower beds of the cretaceous series would seem to belong rather to the oolitic. After describing a section at Saulxce-aux-Bois, M. d'Archiac observes, "On voit qu'ici il y a eu une sorte d'oscillation entre les derniers sédimens jurassiques, et les premières couches crétacées."—Groupe Moyen de la Form. Crét. p. 283.

In the following list I have recorded only such species as I collected and have had time to examine; and with respect to some forms of *Terebratulæ*, I have omitted them for the present, in consequence of the difficulty which their variation in form presents.

List of Farringdon Species.

SCYPHIA.
subfurcata, *Roem.* Ool. t. 17. f. 24 ..... Hils, conglom.
infundibuliformis, *Goldf.* t. 5. f. 2 ..... Hils, conglom.

MANON.
peziza, *Goldf.* t. 1. f. 8, t. 29. f. 8 ..... Oolitic and Neocomian.

TRAGOS.
hippocastanum, *Goldf.*

CRICOPORA.
gracilis, *Goldf.* t. 10. f. 11.

PUSTULOPORA.
madreporacea, *Goldf.* t. 10. f. 12.

VERTICILLIPORA.
anastomosans, *Mant.* sp.

CIDARIS.
variolaris, *Goldf.*

SALENIA.
areolata, *Agass.*

ARCA.
Schusteri, *Roem.* p. 70. t. 9. f. 3. ..... Devizes, conglom.
—— ? Compare with A. biloba, *Roem.*, oolitic. Furze Hills, in ironstone.

CARDIUM.
subhillanum, *Leym.* Casts in ironstone, Furze Hills ..... Neocomian.

NUCULA.
scapha, *d'Orb.* Casts in ironstone, Furze Hills.

OPIS.
neocomiensis, *Leym. & D'Orb.* Cast in ironstone, Furze Hills ..... Neoc. of France.
Mr. Cunnington's collection may possibly contain another sp.

VENUS.
parva, *Sow.* Furze Hills, in ironstone ..... Neoc. of Weald, Isle of Wight.
fenestrata, *Forbes*, Journ. Geol. Soc. vol. i. p. 239. pl. 2. f. 6. Furze Hills, in ironstone. Neoc. of Weald.

EXOGYRA.

OSTRÆA.
carinata, *Sow.*
macroptera, *Sow.*
rectangularis, *Roem.* ..... Neoc. of N. Germany.

PECTEN.
Robinaldinus ?, *D'Orb.* ..... Neoc. of France.
atavus, *Roem.* Ool. t. 18. f. 21. Ironstone, Furze Hills ..... Hils, conglom., Neoc. of France.

TEREBRATULA*.
sella, *Sow.* [*Forbes*, Quart. Journ. Geol. Soc. vol. i. p. 345.]
lata [latissima], *Sow.*
nuciformis, *Sow.* ..... Oolitic. D'Archiac.
oblonga, *Sow.* ..... Oolitic. Von Buch.
truncata, *Sow.* (not T. Asteriana, *d'Orb.*) ... Oolitic (uppermost beds), Germany.
depressa, *Sow.* [Von Buch.
subtrilobata, *Leym.* Mém. Geol. Fr. pl. 15. f. 7–9.
tamarindus, *Sow.* D'Orb. T. Cret. pl. 505. f. 5–10.
Moutoniana, *d'Orb.* [Sharpe, MSS.]
lentoidea, *Leym.*

EMARGINULA.
neocomiensis, *d'Orb.* Devizes. Furze Hills. Neoc. of France. Vassy.

BELEMNITES.
subquadratus, *Roem.* ..... Hils.

NAUTILUS.
——. Compare with N. depressus, *d'Orb.*... Oolitic.

In the question which seems to be raised by the position and contents of the Farringdon deposits, as here described, it is not so much the identity of specific forms which we have to consider as the facies of its fauna as a whole: between deposits which have no species in common, as between the neocomian and the gault and upper greensand group, such a feature is the only one we can take as a means of comparison. An agreement of this sort, when it may exist, may perhaps appear to some as of no great value; if so, this is not the place to controvert such a notion: what is meant by the expression is this, that a genus or genera may be subdivided into natural groups: and that fossil forms often correspond with geological divisions, just as we find like groups among actual forms referable to particular regions of depth or of geographical area; it is this grouping which imparts to a fossil fauna its peculiar facies, as compared with another, when the same generic forms alone are considered. The facies of the liassic *Ammonites* consists in the preponderance of Von Buch's groups of "Arietes" and "Falciferi;" that of the cretaceous *Nautili* in the lines of furrows which cross them transversely. The neocomian ammonite (*A. Nutfieldiensis*, Sow.) is more nearly allied to certain upper oolitic forms than to any from the gault and upper greensand; so much so, that it is constantly quoted as occurring in the Portland beds; and Mr. Morris, in his description of the *Nautilus Saxbyi*, pointed out that it was referable to a group of which all the forms were oolitic. In the same manner the neocomian species of *Opis*, according to M. d'Orbigny, is very like certain oolitic ones; a like result is obtained with reference to the Farringdon *Belemnites*, *Terebratulæ*, corals, and sponges.

* The most abundant *Terebratula* at Farringdon is one which presents great variety of form, and which is evidently the same species quoted so often by continental geologists as *biplicata*; it as often resembles *dimidiata* and *perovalis* of Sowerby, and several neocomian forms of Leymerie and D'Orbigny, and is most probably a form common to a great part of the oolitic and cretaceous series.

The results which I infer from our observations, though the area visited was very limited, are not without some interest and novelty: they are—

1st. That the freshwater conditions of a portion of our Wealden were to some extent contemporaneous with the Portland beds, or belong to the oolitic period.

2nd. That the ironsands and gravels of the counties of Wilts and Berkshire are of the age of the Neocomian formation of the continental geologists.

3rd. That the Neocomian formation is unconformable with, and separated from, the true cretaceous series by a wide interval of denudation.

4th. That the aspect of its fauna is partly oolitic.

5th. That the identity of the materials of the gravel beds of the Farringdon and Portland beds shows the condition of the area of water, as to extent, depth, and direction of distribution, to have been the same for both.

6th. That the Farringdon beds and their equivalents (lower greensand) must therefore be considered as the remains of an independent formation, of which the greater portion was removed by denudation before the deposition of the Gault.

DONATIONS

TO THE

LIBRARY OF THE GEOLOGICAL SOCIETY,

April 1st to June 30th, 1850.

I. TRANSACTIONS AND JOURNALS.

Presented by the respective Societies and Editors.

Académie Royale des Sciences de Paris, Comptes Rendus de l'. Tome xxx. nos. 7–21. Prem. Sem. Deux. Série.

American Journal of Science. Second Series, vol. ix. nos. 26 & 27.

———— Philosophical Society, Proceedings. Vol. v. no. 44.

Asiatic Society (Royal), Journal. Vol. xii. part 2.

Astronomical Society (Royal), Memoirs. Vol. xviii.; and Monthly Notices, vol. ix.

Athenæum Journal, April to June.

British Association, Report of the Nineteenth Meeting of the.

Calcutta Public Library. Report from February to December 1849.

Chemical Society, Quarterly Journal. No. 9.

Cornwall Geological Society (Royal), 36th Annual Report.

Dijon, Académie des Sciences, Mémoires. Années 1845–1848.

France, Société Géologique de, Bulletin. Deux. Série, tome vii. F. 4–13.

Geological Society of London. Plates to Vol. ii. Transactions, First Series. *From the Royal Institution.*

Horticultural Society, Journal. Vol. iv. part 4, and vol. v. parts 1 and 2.

Indian Archipelago, Journal of the. Vol. iv. nos. 1–4.

Montpellier Académie des Sciences et Lettres, Mémoires de la Section des Sciences. Année 1848.

Munich Academy (Royal), Abhandlungen. Vol. v. part 3.—Bulletin, 1849; Almanach, 1849; Buchner, Dr. L. A. Ueber den Antheil der Pharmacie an der Entwicklung der Chemie, 1849.

New York Lyceum of Natural History, Annals. Vol. iv. no. 12, and vol. v. no. 1.

Philadelphia Academy of Natural Sciences, Journal. Vol. iv. no. 12; vol. v. no. 1; and New Series, vol. i. part 4.

Philosophical Magazine, April to June. *From R. Taylor, Esq., F.G.S.*

Puy, Société d'Agriculture, Sciences, Arts et Commerce du. Annales, vols. i.–xiii., and vol. xiv. Prem. Sem.

Society of Arts, Statement of Proceedings preliminary to the Exhibition of Industry of all Nations, 1851.

Torino, Reale Accademia delle Scienze di. Memorie, Seria Seconda, tomo x.

II. GEOLOGICAL AND MISCELLANEOUS BOOKS.

Names in italics presented by Authors.

Admiralty. Sheets completing Vol. i. of Astronomical Observations made at the Royal Observatory, Cape of Good Hope, in the year 1834.

Agassiz, Prof. L. Lake Superior: its Physical Character, Vegetation, and Animals, compared with those of other and similar regions.

———. The Geographical Distribution of Animals.

Béron, P. Système de Géologie et Origine des Comètes, ou très-court résumé du Deuxième Volume de l'Atmosphérologie.

Blackwell, J. K. Report on Ventilation of Mines. *From Sir P. G. Egerton, Bart., M.P., F.G.S.*

Bouchard-Chantereaux, M. Mémoire sur un Nouveau Genre de Brachiopodes, formant le Passage des Formes Articulées à celles qui ne le sont pas.

Brent, G. S. Notes on a Map of the World. Fasc. I. On the Configuration of Continents.

British Museum. Report of the Commissioners appointed to inquire into the Constitution and Government of the. *From Sir P. G. Egerton, Bart., M.P., F.G.S.*

Conrad, T. A. Descriptions of one new Cretaceous, and seven new Eocene Fossils.

Daubeny, Charles, M.D. On the Influence of Carbonic Acid Gas on the Health of Plants.

Davidson, Thomas. Mémoire sur quelques Brachiopodes nouveaux ou peu connus.

———. Notes on an Examination of Lamarck's species of Fossil Terebratulæ.

D'Hombres-Firmas, Baron. Suite des Mémoires et Observations de Physique et d'Histoire Naturelle.

———. Itinéraire proposé à la Société Géologique de France, dans sa réunion extraordinaire à Alais, le 30 Août, 1846.

———. Observations sur la Terebratula Diphya.

D'Orbigny, Alcide. Cours Élémentaire de Paléontologie et de Géologie Stratigraphiques. Partie 1. et Tableaux.

———. Paléontologie Française, Terrains Jurassiques, Liv. 51–57, et Terrains Crétacés, Liv. 137–150. *From J. C. Moore, Esq., Sec. G.S.*

Faraday, Michael. Experimental Researches in Electricity (23rd Series). 29. On the Polar or other condition of Diamagnetic Bodies.

Fournet, J. Suite des Études sur la Géologie de la Partie des Alpes.

Gray, James. The Earth's Antiquity in Harmony with the Mosaic Record of Creation.

Homersham, S. C. London (Watford) Spring Water Company. Report to the Directors.

Hopkins, William. On the Transport of Erratic Blocks.

———. On the Internal Pressure to which Rock Masses may be subjected.

Howard, Luke. Papers on Meteorology; Part II. of the Appendix to Barometrographia. *From the Editor, E. W. Brayley, Esq., F.G.S.*

Jackson, C. T. Remarks on the Geology, Mineralogy, and Mines of Lake Superior.

———. On the Geological Structure of Keweenaw Point.

Mantell, G. A., LL.D. A Day's Ramble in and about the Ancient Town of Lewes.

Marcel de Serres, Dubrueil, et Jeanjean. Recherches sur les Ossemens Humatiles des Cavernes de Lunelbeil. *From Lord Alfred Churchill, F.G.S.*

Martin, John. Outline of a Comprehensive Plan for Diverting the Sewage of London, &c.

Morris, John. A Tabular View of the principal Fossiliferous Deposits of the British Isles. (2 copies.) *From J. C. Nesbit, Esq., F.G.S.*

Mylne, R. W. Sections of the London Strata.

Perrey, Alexis. Mémoires sur les Tremblements de Terre (various).

Phillips, John. Report on the Ventilation of Mines and Collieries. *From Sir P. G. Egerton, Bart., M.P., F.G.S.*

Ponzi, Giuseppe. Osservazioni Geologiche fatte Lungo la Valle Latina.

Reeve, Lovell, and Arthur Adams. The Zoology of the Voyage of H.M.S. Samarang, No. 6. Mollusca. Part 2.

Report on Accidents in Coal Mines. *From Sir P. G. Egerton, Bart., M.P., F.G.S.*

Trimmer, Joshua. Proposals for a Geological Survey, specially directed to Agricultural Objects.

———. On the Geology of Norfolk as illustrating the Laws of the Distribution of Soils. (2 copies.)

GEOLOGICAL SOCIETY OF LONDON.

ANNUAL GENERAL MEETING, FEB. 15, 1850.

REPORT OF THE COUNCIL.

THE Council of the Geological Society have the satisfaction of announcing to the Members the flourishing condition of the finances and other affairs of the Society. The lists show, however, a small diminution in the aggregate numbers of Fellows.

During the past year 16 new Fellows have been elected who have paid their admission-fees, besides 1 elected in a former year who has paid his admission-fee during the year; increase 17. The deaths on the other hand have been 14, besides 8 resignations and 1 removal; decrease 23. There has been no change in the numbers of Foreign or Honorary Members. Amongst personages of Royal Blood they have been honoured by the election of H.R.H. Prince Albert, while they have to lament the loss of H.M. Christian VIII., late king of Denmark. The total diminution in the numbers of the Society has therefore been 6, thus reducing the number from 894 at the close of 1848 to 888 at the close of 1849.

The excess of income over expenditure announced in the former Report has continued during the past year, the balance in favour of the Society amounting to £63 11*s*. 2*d*. in addition to the excess in the preceding year of £225 9*s*. 6*d*. This is the more satisfactory, inasmuch as the Council have been under the necessity of laying out a larger sum than usual in painting and repairs, and have also paid an additional sum to the Assistant Secretary for additional services in the Museum.

The number of existing compounders at the close of the past year was the same as on the previous anniversary, one compounder having died, and one Member having compounded during that period, whose composition has been invested in the funds. The total amount received from 131 compounders has been £4126 10*s*. The amount of Stock held by the Society at the close of 1848 was £3563 15*s*. 11*d*.;

whereas at the close of 1849 it amounted to £3597 10*s.* 5*d.*, of which the estimated value on the 31st Dec. 1849 (Consols being at 96) was £3453.

The Council have to announce the completion of the fifth volume of the Journal, and the publication of the first part of Vol. VI.

In consequence of the appointment of Mr. Nicol to the Professorship of Geology in Queen's College, Cork, the Council have been again compelled to take steps to find a successor who should satisfactorily fill the office of Assistant Secretary. Hitherto, Mr. Nicol's duties at Cork have not compelled him to relinquish the task of editing the Journal, but the Council are now desirous of losing no time in making some permanent arrangement, which will, they trust, include an efficient control and superintendence of the Collection.

They have already been enabled during a portion of the past year, owing to the improved state of the Society's finances, to make such arrangements with Mr. Nicol, that he was enabled to give additional daily attendance at the apartments of the Society, devoting such time to the arrangement and superintendence of the Museum.

Carrying out the resolutions of the Council announced in their address last year, they have the satisfaction of stating that, owing to the active and zealous co-operation of several of their Members, many of the inorganic and duplicate specimens have been removed from the Foreign Collection, and the valuable organic specimens hitherto consigned to the crypts for want of space, have been, or are in the act of being, incorporated with the Collection.

Considerable progress has also been made in the arrangement of the Foreign Collection, the details of which will be more appropriately described in the Museum Report. The system adopted by the Council combines, as they trust, all the principal advantages contemplated either in a geographical or a stratigraphical arrangement.

The Council have instructed Mr. Nicol to arrange various sets of the duplicate specimens of fossils, rocks and minerals, for the purpose of presentation to some of the many public bodies which have made application for them during past years. One of these sets is intended for Queen's College, Cork. Such a distribution will tend to the extension of geological knowledge, and will therefore, they feel confident, meet with the approbation of the Members generally.

In compliance with the wish generally expressed last year, the Secretaries were authorized to prepare, and have prepared, an alphabetical catalogue of the books in the Library; the Council trust that the facilities of reference thereby offered will be satisfactory to the Fellows. They have also resolved that the sum of £50 be expended on the Library, with a view to procure certain standard works in very general request, the acquisition of which will materially add to the efficiency and practical utility of the Library.

In conclusion they have to announce that they have awarded the Wollaston Palladium Medal for the present year to Mr. William Hopkins, M.A. of St. Peter's College, Cambridge, for his researches illustrative of the application of Mathematics and Physics to Geology, as shown in his Memoirs published in the Philosophical Transactions,

in the Cambridge Philosophical Transactions, and in the Transactions of this Society; and that they have granted the balance of the proceeds of the Donation Fund for the present year, amounting to £31 5*s.* 6*d.*, to Mr. John Morris, F.G.S., for the purpose of aiding him in the publication of the New Edition of the Catalogue of British Fossils on which he is now engaged.

Report of the Museum and Library Committee.

The Committee beg leave to present the following Report on the present state of the Library and Museum, and the changes made in them during the past year.

Museum.

British Collection.—Mr. Nicol has looked carefully through every drawer in this collection, and fixed down all the specimens which had broken loose, and seen to the good order of the whole. His Report to the Council of May 16, 1849, contains such full details on the subject that the Committee think it sufficient to refer to it.

During the year the specimens of Azoic rocks have been removed from the two cabinets in which they were contained and have been packed up in paper parcels in accordance with the order of the Council, and under the direction of Mr. Greenough; these parcels are now placed in the recesses below the windows in the Lower Museum. There still remain in this collection nearly 250 drawers full of inorganic specimens, many of which might be advantageously removed to make room for such specimens as may be presented to the Society, and to allow of many being better displayed which are now inconveniently crowded; but the general good order in which this collection has been left by our previous Curators leaves little to be done to it beyond occasional attention to the condition of the drawers, and the proper insertion of fresh specimens as they are received from time to time.

Foreign Collection.—The great changes which have been made in this department, in carrying out the vote of the Council of March 21, render it necessary to report upon it at some length.

The Committee appointed to carry out those changes commenced by separatiug all the specimens of Minerals and Rocks from the Organic Remains; and this they will treat of separately.

Rocks.—In accordance with the vote of the Council of Jan. 31, the unarranged Foreign Rock specimens were brought up from the vaults that they might be examined together with those already in the Upper Museum, and a selection was made from the whole collection thus brought under review upon the following principle, as want of space rendered it impossible to keep the whole in the Upper Museum.

The Committee determined to retain in drawers collections from certain well-described districts of igneous and volcanic rocks, which may serve as terms of comparsion with other districts: under this head come Naples, Auvergne, the Siebengebirge, &c., and also the

Freyberg collection of rocks which has an historic interest. They have also retained in the drawers the specimens of rocks from countries which have not been mapped geologically or are very imperfectly known, as these specimens are often the only sources of information with regard to the geology of such countries.

The following is the catalogue of this part of the Collection in the order in which they will now be found; the whole are in excellent order and well-labelled.

	Drawers.		Drawers.
Spitzbergen	2	Eastern Archipelago	3
Iceland	5	Egypt	3
Faroe Islands	2	Greenland	5
Hungary	16	Northern regions of N. America	12
Freyberg	10	Labrador	6
The Hartz	6	Canada, &c	5
Wurtemberg	10	Brazil	8
Siebengebirge, &c.	8	Buenos Ayres	1
The Eifel	3	Sandwich Isles	1
Haute-Loire	1	Strait of Magellan	2
Auvergne	6	New Zealand	2
Ponza Islands	2	Van Diemen's Land	1
Naples, &c	13	New Holland	9
India	18	Greece	2
Burman Empire	5		
China	1		

Such sets of specimens which it seemed desirable for the Society to preserve, but which being very seldom referred to need not have drawers appropriated to them, have been packed up in parcels, carefully labelled, arranged geographically and placed in the crypt.

List of Specimens in the Crypt in parcels from the Foreign Collection.

	Parcels.		Parcels.
A.X. Sweden	2	F.X. Granada	1
		,, Bavaria	1
B.X. Norway	4	,, Spain	1
,, Styria	1	,, South of Spain	1
		,, Switzerland	1
B.O. Cape of Good Hope	1		
,, St. Helena	1	G. Switzerland, Canton de Valais	1
,, Isle of France	1	,, Switzerland, Canton de Vaud	2
C.X. Russia, Crimea	1	,, Switzerland, Canton Tessino	1
C.O. Cape de Verde	1	G.O. Canada	1
,, Ascension Island	1		
,, Madeira	1	H. Euganean Hills	1
		H.O. New England	2
E. Piedmont	1	,, Newfoundland	1
		,, New Jersey	1
F. Chamouni	1		
F. Duchy of Savoy	2		

		Parcels.
I.	Syria	2
,,	,, Beyrout	1
,,	,, Mount Lebanon	1
,,	Laacher See	1
,,	Sicily	1
I.O.	New York	1
,,	New Zealand	1
,,	New England	1
K.	Persia, Bombay	7
L.	Jamaica	1
,,	Hydrabad	2
,,	Nagpur	2
,,	Malabar	2
,,	Beghapore	1
,,	Indian Peninsula	1
,,	India, Mysore	1
L.O.	California	1
M.	St. Vincent, Guadaloupe and St. Lucia.	1
,,	St. Helena	1
,,	Bengal	1
M.O.	Trinidad	1
,,	Panama	1
,,	Mauritius, Island of	1
O.	Java	1
,,	Sumatra	1
,,	Borneo	1
,,	China, &c.	1
R.	Rhine, Duplicate Rocks.	1
,,	Crystalline Rocks	1

There is in the Upper Museum a collection of rock-specimens arranged mineralogically for assisting the study of rocks: this has not been touched for many years and is very imperfect. The Committee regard the present as a favourable opportunity for improving it, and they recommend that a selection be made from among the duplicate specimens to render this collection as perfect as possible. Had time permitted, the Committee would have made such a selection and submitted it for the approval of the Council; but not having been able to do so, and not wishing on that account to delay the disposal which the Council may wish to make of the vast accumulation of duplicates which encumber the Society's rooms, they have set aside a portion of the duplicates out of which the required selection may be made hereafter.

Minerals.—Acting on the vote of the Council of Feb. 21, Mr. Pratt caused all the specimens of minerals in the vaults to be brought up to the tables of the Lower Museum, where they were united with those which had been removed from the drawers of the Foreign Collection in the Upper Museum, and the whole were then examined and compared with the specimens arranged in the Mineral Collection in the Library, to which were added all such specimens as could improve that collection. The remainder were set aside as duplicates.

Foreign Organic Remains.—Following the plan laid down by the Council on March 31, the Committee divided this part of the collection in the Upper Museum into the following great geographical divisions:—Europe.

America, divided into British North America, &c.
,, ,, United States.
,, ,, West Indies.
,, ,, South America.

Asia.
Australia, &c.
Africa.

The Council having directed that the three first of these divisions should be arranged stratigraphically, and the five last should be placed in geographical order, the Committee proceeded so to arrange them, adhering strictly to the rule laid down by the Council, that the specimens from different countries or important districts should not be mixed in the same drawer. The following is the progress which has been made in this part of the labour :—

Europe, Tertiary Series.—The following drawers have already been arranged in order :—

Cabinet A.

1st drawer	Fossil shells from Uddevalla.
2nd & 3rd drawers..	Breccia from Gibraltar.
4th drawer	Shells from the Loess. Rhine.
5th to 9th drawers..	Shells from Sicily. Pliocene.
10th & 11th drawers	Shells from Touraine.
12th drawer	Shells from Prov. d'Anvers.
7 drawers	Shells from Bordeaux. Miocene.

Cabinet B.

5 drawers.	Shells from Turin. Miocene.
4 „	Impressions of Leaves and Fish in the Brown Coal of Germany.
8 „	Fossils, various, from Malta and Gozo.

Cabinet C.

4 drawers.	Rocks and Fossils from Malta.
2 „	———————— Gibraltar.
1 „	———————— Madeira.
1 „	———————— Azores.
2 „	———————— Spain.
2 „	———————— Piacenza.
1 „	———————— Belgium.

Cabinet D.

2 drawers.	Shells, &c. from Lisbon.
3 „	Plants, Insects and Fishes from the freshwater deposits at Aix in Provence.
2 „	Vegetable Impressions. Samos.
1 „	Freshwater Shells from Smyrna.
2 „	Fish, &c. from the Province of Verona.
5 „	Shells, &c. from Malaga.

Cabinet E.

1 drawer.	Shells, &c. from Bassano, &c. Eocene.
14 „	Marine and Freshwater Shells from the Paris Basin.

Centre Cabinet.

Nos. 9 to 15 inclusive. Jaws, Teeth, Bones and Casts of Bones from the Eocene freshwater deposits in the neighbourhood of Paris.

No. 16. Bones and teeth of *Ursus Spelæus* from the Caves of Echenoz near Vesoul, France.

Europe, Secondary Series, arranged as follows:—

Faxoe Limestone..	1	drawer.	
Schneeberg	2	,,	
Maestricht	7	,,	viz. Zoophytes .. 3 Conchifera .. 3 Mollusca .. 1
Belgium	9	,,	from Louisberg, Aix-la-Chapelle, &c.
France	11	,,	viz. Cretaceous and Oolitic 7 Lias ..... 1 Trias 3
Neuchâtel	1	,,	Neocomian.
Sardinia	2	,,	Cretaceous.
Hanover	1	,,	Muschelkalk.
Baden	1	,,	do.
Thuringia	1	,,	do.
Mansfeld	2	,,	Copper-slates.
Bavaria	15	,,	Mostly Oolitic.
Wurtemberg	4	,,	Oolitic.
Spain	1	,,	do.
Portugal	1	,,	Cretaceous.
Russia	2	,,	
Crimea.....	2	,,	Cretaceous.
Sicily	1	,,	
Eschweller	1	,,	Formation doubtful.
Glaris	2	,,	do. do.

The above are already in sufficient order for convenient reference; most of the specimens have the localities marked and some of the species are named; but the whole series requires a farther review, especially with a view to discarding useless specimens and duplicates.

Europe, Palæozoic Series.—Fifty-two drawers belonging to this series are already placed in the cabinets; a few of these had been arranged in excellent order by Mr. Lonsdale, but the rest will require considerable labour to bring them into order, as they are crowded both with specimens of no value and with duplicates to such an extent that the Committee think it useless to offer a list of them in their present condition. When arranged, this part of the collection will be fully equal in interest to the other series, containing very rich collections from the Silurian formations of Norway, Sweden and Russia, the Devonian beds of the Rhenish Provinces and the Devonian and Carboniferous formations of Russia, besides minor collections from other countries.

British North America.—Twenty-seven drawers already arranged in fair order.

United States.—Forty-six drawers, the arrangement of which has been about half completed. The collection of Palæozoic Shells, &c. from the Western States and of Coal-Plants from Pennsylvania, &c., are of great interest.

West Indies, viz.:—Antigua	17	drawers.
Jamaica	1	„
Bermuda	4	„
Barbadoes	4	„
St. Domingo	2	„
South America	6	„
Egypt	9	„
Madagascar	1	„
Australia	13	„
Van Diemen's Land	4	„
Asia	56	„

Little has been done to the latter divisions of the collection beyond placing the drawers in those cabinets in which they are to remain. The collections from Pondicherry and Cutch and part of the West Indian series were found in good order: most of the rest will require much labour upon their arrangement.

Besides what have been mentioned above, there still remain a few drawers in the Foreign Museum the contents of which have to be sorted and then worked into their proper places in the cabinets. A very large number of specimens, many of them of great interest, which have long lain unseen in the crypts, will have to be brought into the Foreign Collection upstairs, to which they will form a most valuable addition; and some recent donations (including the rich collection from the Cape of Good Hope, sent by Mr. Atherstone) have to be incorporated. It is not possible at present to form any accurate idea of the space these additions will occupy, but so much room has been made in the Upper Museum by the removal of rock-specimens and the discarding mere rubbish and duplicates, and so much more space may yet be gained by a more thorough weeding of the contents of the drawers, that the Committee have little doubt that the space will be found more than sufficient for the whole of the Foreign Collection at present belonging to the Society.

Collections preserved in the Crypts.—Besides what have been already mentioned under the heads of Rocks and Minerals, there still remain downstairs more than 100 boxes of Foreign and British specimens.

The Foreign specimens have been roughly examined by the Committee; many are quite valueless and had better be thrown away; many are duplicates of specimens upstairs which might be given away: but there are also very many valuable specimens which should be placed in the drawers of the Foreign Collection. It will be a work of considerable labour to separate these, but as it is not possible that this could be done properly while they remained below in the dark, the Committee have had them removed to the room on the ground-floor, and have commenced a detailed examination of them. They recommend that the boxes remain where they are until this examination be completed and their contents finally disposed of.

Duplicates.—It has been stated above that the Committee have already set apart a large number of duplicate specimens of Rocks and Minerals which were only an encumbrance to the collection of

the Society, but which may be of great value to the Museums of other Institutions. Up to the present time, the Council have only presented a collection of igneous and volcanic rocks to the Museum of Practical Geology, and a set of minerals and of rock-specimens to the Museum of the Queen's College at Cork: according to the last vote of the Council, the remainder of the duplicates of Rocks and Minerals are now being divided into sets convenient for presentation, which the Committee recommend to be presented to other Institutions in which they may contribute to the spread of the science.

The Committee have not yet made sufficient progress in the arrangement of the Foreign Fossils, to propose to the Council any immediate distribution of duplicates of them; but they hope that the work which they have begun will be pushed forward by the Council, and that all the duplicates both of British and Foreign Fossils may be removed from the collections and from the crypts, and may be distributed where they may conduce to the progress of Geology.

The Committee cannot conclude without impressing on the Council the necessity of authorizing the Curator of the Museum to reject all valueless specimens as they enter the Society's apartments, either under the control of one of the Secretaries or of a Committee appointed for the purpose. This would be a very slight labour if it were done week by week, and had it been done formerly would have saved half the work of the present Committee. To avoid such labour being again required, it is recommended that as soon as new specimens have been exhibited in the Meeting-room they should be examined, the worthless portion thrown away, the duplicates separated and packed up, and the rest sent at once to the place they are intended to occupy in the collections.

Library.

During the past year many unbound volumes have been bound. As the shelves in the Library were overfull, space has been made by removing a number of books to the shelves in the Council-room, selecting for removal such periodicals as form long series and are seldom referred to.

In accordance with the wish which has been expressed by many of the Members, a copy of the Catalogue has been arranged alphabetically with reference to the shelves occupied by the books, which proves a great assistance to those who make use of the Library.

The Committee have every reason to be satisfied with the condition of the Library; but they hope that the Council will be able to devote a moderate sum to the purchase of new books, and to completing a few works which are now imperfect.

Signed, DANIEL SHARPE.
SEARLES WOOD.
24th January, 1850. S. P. PRATT *per* D. SHARPE.
JOHN MORRIS.

Comparative Statement of the Number of the Society at the close of the years 1848 *and* 1849.

	Dec. 31, 1848.		Dec. 31, 1849.
Compounders	131		131
Residents	233		228
Non-residents	457		456
	821		815
Honorary Members	19	19	
Foreign Members	50	50	
Personages of Royal Blood	4—73	4—73	
	894		888

General Statement explanatory of the Alteration in the Number of Fellows, Honorary Members, &c. at the close of the years 1848 *and* 1849.

Number of Compounders, Residents and Non-residents, December 31, 1848			821
Add, Fellow elected during a former year, and paid in 1849	Non-resident	1	
		— 1	
Fellows elected, and paid, during 1849	Residents	11	
	Non-residents	5	
		—16	
		—	17
			838
Deduct, Compounder deceased		1	
Residents „		7	
Non-residents „		6	
Resigned		8	
Removed		1	
		—	23
Total number of Fellows, 31st Dec. 1849, as above			815
Number of Honorary Members, Foreign Members, and Personages of Royal Blood, December 31, 1848			73
Add, Personage of Royal Blood elected in 1849			1
			74
Deduct, Personage of Royal Blood deceased			1
		As above	73

Number of Fellows liable to Annual Contribution at the close of 1849, *with the Alterations during the year.*

Number at the close of 1848		233
Add, Elected and paid in 1849		11
Non-residents who became Resident		4
		248
Deduct, Deceased	7	
Resigned	6	
Compounded	1	
Became Non-resident	5	
Removed	1	
	—	20
As above		228

DECEASED FELLOWS.

Personage of Royal Blood (1).

His Majesty Christian VIII. King of Denmark.

Compounder (1).

Samuel Turner, Esq.

Residents (7).

Hon. Charles Ashburnham. | Major T. H. S. Clerke.
Earl of Auckland. | A. L. Gower, Esq.
T. W. Beaumont, Esq. | R. Heathfield, Esq.
Bishop of Norwich.

Non-residents (6).

Robert Anstice, Esq. | S. Hibbert-Ware, M.D.
William Bullock, Esq. | Right Hon. Maurice Fitz-
Frederick Dixon, Esq. | gerald, Knight of Kerry.
George Silvertop, Esq.

Personage of Royal Blood elected a Fellow during the year 1849.

His Royal Highness Prince Albert of Saxe Coburg and Gotha, K.G., F.R.S.

The following Persons were elected Fellows during the year 1849.

March 7th.—Edward C. Ravenshaw, Esq., Conduit Street; and Henry James Slack, Esq., Sion College.

—— 21st.—James G. Lynde, jun., Esq., Great George Street; Rear-Admiral Sir Thomas Trowbridge, G.B., Eaton Place; and M. Sylvain Van de Weyer, Portland Place.

April 4th.—Rev. Ebenezer Prout, Camberwell; John Bentley, Esq., Portland Place; and Lieut.-Col. William Reid, Baker Street, Portman Square.

May 2nd.—Ebenezer Rogers, Esq., Abercarne, Newport; and Samuel Blackwell, Esq., Dudley.

—— 16th.—Christopher Bagot Lane, Esq., Bennett's Hill, Birmingham.

—— 30th.—Peter M. Duncan, M.D., Colchester; and John Lane Oldham, Esq., Audley End, Essex.

November 21st.—Charles Meyer, Esq., Buckingham Palace.

December 5th.—Robert A. Slaney, Esq., M.P., Walford Manor, Shrewsbury; Ernest Noel, Esq., Hornsey; William Lee, Esq., Gwydyr House, Whitehall; Cornelius Nicholson, Esq., Bernard Street, Russell Square; and Count Achille de Zigno, Padua.

The following Donations to the Museum have been received since the last Anniversary.

British Specimens.

Ammonites, from the Marlstones, Deddington; presented by C. Faulkner, Esq., F.G.S.

Plagiostoma, from the Lias near Adderley, Cheshire, and Bone of Deer from Peat Bog; presented by Richard Corbet, Esq.

Specimens of Fossil Fishes from the Mountain Limestone of Armagh; presented by Captain T. Jones, R.N., M.P., F.G.S.

Specimens from the London Clay at Chalk Farm, and from the Gravel-pits of Muswell Hill; presented by N. T. Wetherell, Esq., F.G.S.

Fossils from the Silurian rocks of Peeblesshire; presented by Prof. J. Nicol, F.G.S.

Fossils from the Silurian rocks of Ayrshire and Wigtonshire; presented by J. C. Moore, Esq., Sec.G.S.

Slab from the Isle of Arran in the Bay of Galway; presented by The Very Rev. the Dean of Westminster, F.G.S.

Specimens of Plants from the Keuper Sandstone of Longdon, near Tewkesbury, and of a Coral from the Lower Oolite near Cheltenham; presented by the Rev. P. B. Brodie, F.G.S.

Two specimens of *Gorgonia Keuperi* from the Keuper Sandstone, Leicester; presented by Prof. Ansted, F.G.S.

Foreign Specimens.

Impressions of Feet of Birds, Cat, &c., in Red Mud, from the Bay of Fundy; and Tertiary Fossil Shells from the Island of San Domingo; presented by Sir Charles Lyell, Pres. G.S.

Shells from the Beds below the Drift at Nantucket, Massachusetts; presented by Messrs. E. Desor and E. Cabot.

Eocene Shells from Clayborne, Alabama, from Mr. Koch's Collection; presented by W. J. Hamilton, Esq., Sec. G.S.

Specimens of Gold Ore from Brazil; presented by the Rt. Hon. Sir Henry Ellis, F.G.S.

Fossils from the Lignite Formation of the Wetterau and Vogelsgebirge, and specimens of Rocks and Minerals from Germany; presented by Dr. M. A. Klipstein.

Silurian Fossils from Sardinia; presented by Sir R. I. Murchison, V.P.G.S.

Fossils from Suez and Aden, and Fishes from Mount Lebanon; presented by the Rev. Robert Everest, F.G.S.

Specimens of Rocks and Fossils from Western Australia; presented by J. W. Gregory, Esq.

Lias and Tertiary Fossils from the Cape of Good Hope (Eastern Province); presented by Dr. W. G. Atherstone.

Collection of Rocks and Fossils from Hobart Town; presented by J. E. Bicheno, Esq., F.G.S.

Specimens of Fossils from near Fingal, Van Diemen's Land; presented by Lieut. W. H. Breton, R.N., F.G.S.

Rocks and Minerals from the Coast of Greenland and the N.E. Coast of America, collected during the Expedition of Sir John Ross; presented by the Lords Commissioners of the Admiralty.

Cast of Rhinoceros Tooth from Red Crag at Felixstow, Suffolk, and two Casts of Antlers of Deer; presented by Dr. W. B. Clarke.

Charts and Maps.

The Charts, &c., published by the Admiralty during the year 1848; presented by Rear-Admiral Sir Francis Beaufort, by direction of the Lords Commissioners of the Admiralty.

Geographical Map of the Globe, and Map of Lower Egypt, Sinai and Arabia Petræa, by A. Petermann; presented by the author.

Geognostische Karte von Thüringen, von Bernhard Cotta. Sections 1 to 4; presented by the author.

Engraving of John Macculloch, M.D.; presented by Mrs. Macculloch.

Drawings of Fossils from the Crag near Woodbridge; presented by W. Whincopp, Esq.

A Natural Scale of Heights, by the application of which the measures of different countries are reduced to a common measure, constructed by Miss Colthurst (2 copies); presented by G. B. Greenough, Esq., V.P.G.S.

The following List contains the Names of all the Persons and Public Bodies from whom Donations to the Library and Museum were received during the past year.

Academy of Sciences of Paris.
Admiralty, The Right Hon. the Commissioners of the.
American Academy of Arts and Sciences.
American Association.
American Philosophical Society.
Ansted, Prof. D. T., F.G.S.
Ashmolean Society.
Athenæum, Editor of.

Atherstone, Dr. W. G.
Austin, Thos. jun., Esq., F.G.S.

Beaufort, Rear-Admiral Sir F., Hon. Mem. G.S.
Bellardi, Sig. L.
Berwickshire Naturalists' Club.
Bland, T., Esq., F.G.S.
Brayley, E. W. jun., Esq., F.G.S.
British Association for the Advancement of Science.
Brodie, Rev. P. B., F.G.S.
Brongniart, Prof. A., For. Mem. G.S.
Buch, L. von.
Buckman, James, Esq., F.G.S.
Bunbury, C. J. F., For. Sec. G.S.
Burmeister, Dr. Hermann.

Cabot, M. E.
Calcutta Library, Curators of.
Carpenter, W. B., M.D., F.G.S.
Carter, H. J., Esq.
Chemical Society of London.
Clarke, Dr. W. B.
Corbet, R., Esq.
Cotta, Herr Bernhard.

Dana, J. D., Esq.
Darwin, Charles, Esq., F.G.S.
Davis, Captain.
Delaunay, M.
Dent, E. J., Esq.
Desor, M. C.
D'Orbigny, M. C.
Dublin University Museum.

Elie de Beaumont, M. L., For. Mem. G.S.
Ellis, Right Hon. Sir Henry, K.C.B., F.G.S.
English, H., Esq.
Everest, Rev. Robert, F.G.S.

Fairbairn, William, Esq.
Falconer, Hugh, M.D., F.G.S.
Faraday, M., Esq., D.C.L., F.G.S.
Faulkner, C., Esq., F.G.S.
Forbes, Prof. J. D., F.G.S.
Frodsham, Charles, Esq.

Garner, Robert, Esq.
Geological Society of Dublin.
Geological Society of France.
Gibbes, R. W., M.D.
Göppert, Prof.
Gregory, J. W., Esq.
Guyot, M. A.

Haidinger, Herr W.
Hamilton, W. J., Esq., Sec. G.S.
Hausmann, Prof. J. F. L., For. Mem. G.S.
Heniker, J. S., Esq.
Hennessy, Henry, Esq.
Hogg, John, Esq.
Horticultural Society.
Hutton, Captain Thomas, F.G.S.

Indian Archipelago Journal, Editor of.

Jerwood, James, Esq., F.G.S.
Jobert, M. A. C. G.
Jones, Captain T., R.N., F.G.S.

Klipstein, Dr.
Kutorga, Dr. S.

Leeds Philosophical Society.
Logan, J. R., Esq., F.G.S.
Logan, W. E., Esq., F.G.S.
Lubbock, Sir J. W., Bart., F.G.S.
Lyell, Sir Charles, Pres. G.S.

M'Coy, F., Esq.
Macculloch, Mrs.
Mantell, G. A., LL.D., F.G.S.
Moore, J. C., Esq., Sec. G.S.
Morris, John, Esq., F.G.S.
Murchison, Sir R. I., V.P.G.S.

Nattali, M. A.
Neuchatel, Société des Sciences Naturelles de.
Newbold, Captain.
Newcastle on Tyne, Literary and Philosophical Society of.
Nicol, Prof. James, F.G.S.

Northumberland, Natural History Society of.

Oldham, Prof. T., F.G.S.

Palæontographical Society.
Paris, Muséum d'Histoire Naturelle de.
Pattison, J. R., Esq., F.G.S.
Petermann, A., Esq.
Philadelphia, Academy of Natural Sciences.
Phillips, John, Esq., F.G.S.
Pissis, M.

Quetelet, M. A.

Ramsay, Prof. A. C., F.G.S.
Reeve and Co., Messrs.
Reid, Lieut.-Col. William, F.G.S.
Rogers, Prof. H. D., For. Mem. G.S.
Roux, M. W.
Royal Academy of Belgium.
Royal Academy of Berlin.
Royal Academy of Munich.
Royal Academy of Turin.
Royal Agricultural Society of England.
Royal Asiatic Society.
Royal Astronomical Society.
Royal College of Surgeons.
Royal Cornwall Polytechnic Society.
Royal Geographical Society.
Royal Geological Society of Cornwall.
Royal Institution of Cornwall.
Royal Irish Academy.
Royal Society of Arts and Sciences of Mauritius.
Royal Society of Edinburgh.
Royal Society of London.
Royal Society of Van Diemen's Land.

Saint-Claire Deville, M. Ch.
Sharpe, D., Esq., F.G.S.
Silliman, Prof., M.D., For. Mem. G.S.
Stevenson, W. F., Esq.
St. Petersburg, Imperial Academy of.
St. Petersburg, Mineralogical Society of.

Taylor, R., Esq., F.G.S.
Tennant, Prof. J., F.G.S.
Tylor, A., Esq., F.G.S.

Vaudoise Society.

Washington, Smithsonian Institution of.
Westminster, The Very Rev. the Dean of, F.G.S.
West Riding of Yorkshire, Geological and Polytechnic Society of the.
Wetherell, N. T., Esq., F.G.S.
Whincopp, W., Esq.

Zigno, Count Achille de.
Zoological Society.
Zurich, Natural History Society of.

List of PAPERS *read since the last Anniversary Meeting, February 16th*, 1849.

1849.

Feb. 21st.—On the Gypsum of Plaister Cove in the Strait of Canseau, by J. W. Dawson, Esq.; communicated by the President.

———— On the Tertiary and Recent beds at Nantucket, in Massachusetts, by MM. E. Desor and Ed. C. Cabot; communicated by the President.

———— Notes on some recent Foot-prints on Marl in Nova Scotia, by Sir Charles Lyell, Pres. G.S.

1849.

March 7th.— On some Fossiliferous beds overlying the Red Crag, at Chillesford, near Orford, Suffolk, by Joseph Prestwich, jun., Esq., F.G.S.

——— On the position in which Fossil Shells occur in the Red Crag, by J. R. Thomson, Esq.; communicated by Prof. Ansted, M.A., F.G.S.

March 21st.— Description of Erect Sigillaria with Conical Tap-roots, from the Sydney Coal, Cape Breton, by R. Brown, Esq.; communicated by the President.

——— Notice of Recent Researches in Asia Minor, by M. P. de Tchihatcheff; communicated by Sir R. I. Murchison, V.P.G.S.

April 4th.— On Tylostoma, a proposed genus of Gasteropodous Mollusks, by Daniel Sharpe, Esq., F.G.S.

——— Additional remarks on the Geology of part of Asia Minor, by W. J. Hamilton, Esq., Sec. G.S.

April 18th.—Palichthyologic Notes, No. 3.—On the Ganoidei Heterocerci of Agassiz, by Sir P. G. Egerton, Bart., M.P., F.G.S.

——— On the Tertiary beds of the Great Glen of Scotland, by the Rev. J. G. Cumming, F.G.S.

May 2nd.—On Sigillaria, and some Spores found in its Roots, by E. W. Binney, Esq.; communicated by the President.

——— On the Microscopic Structure of Nummulites, Orbitolites, and Orbitoides, by W. B. Carpenter, M.D., F.G.S.

May 16th.— On some Tertiary beds in the Island of San Domingo, by J. C. Moore, Esq., Sec. G.S.

——— Observations on the Silurian Strata of the South-East of Scotland, by James Nicol, Esq., F.G.S.

May 30th.— On the Superficial Detritus of the Alps as compared with that of Northern Europe, by Sir R. I. Murchison, V.P.G.S.

June 13th.—On the Valley of the English Channel, by R. A. C. Austen, Esq., F.G.S.

Nov. 7th.—On Nerinæa, with species found in Portugal, by Daniel Sharpe, Esq., F.G.S.

——— On productive Iron Ore in the Eocene formations of Hampshire, by Alfred Tylor, Esq., F.G.S.

——— On the Sydney Coal-Field, Nova Scotia, by R. Brown, Esq.; communicated by the President.

Nov. 21st.—On a Cutting in the Buckingham Railway, by W. Stowe, Esq.; communicated by The Very Rev. the Dean of Westminster, F.G.S.

——— On the Secondary district of Portugal, by Daniel Sharpe, Esq., F.G.S.

Dec. 5th.—On the Age of the Upper Tertiaries in England, by S. V. Wood, Esq., F.G.S.

——— On Mammalian Remains found at Brentford, by John Morris, Esq., F.G.S.

Dec. 19th.—On Craters of Denudation and the Structure of Volcanic Cones, by Sir Charles Lyell, Pres. G.S.

1850.

Jan. 9th.—Observations on Dudley Trilobites, by T. W. Fletcher, Esq., F.G.S.

———— Remarks on the Inferior Oolite near Cheltenham, by the Rev. P. B. Brodie, F.G.S.

———— Letter from G. F. Ruxton, Esq., to Prof. Daubeny, M.D., F.G.S., on Volcanic Rocks in Northern Mexico.

———— Letter from Prof. Eugene Sismonda to Sir R. I. Murchison, V.P.G.S., on the discovery of a nearly perfect Skeleton of *Mastodon angustidens* near Asti in Piedmont.

Jan. 23rd.—On the Structure of the Deposits between the London Clay and the Chalk. Part I. On the Basement bed of the London Clay, by Joseph Prestwich, jun., Esq., F.G.S.

Feb. 6th.—On the Pseudo-Volcanic Rocks of the Papal States and adjacent parts of Italy, by Sir R. I. Murchison, V.P.G.S.

After the Reports had been read, it was resolved,—

That they be received and entered on the Minutes of the Meeting; and that such parts of them as the Council shall think fit, be printed and distributed among the Fellows.

It was afterwards resolved,—

1. That the thanks of the Society be given to G. B. Greenough, Esq., Leonard Horner, Esq., and Dr. G. A. Mantell, retiring from the office of Vice-President.

2. That the thanks of the Society be given to J. S. Bowerbank, Esq., Dr. W. B. Carpenter, Captain Henry James, Lieut.-Col. Portlock, and The Very Rev. the Dean of Westminster, retiring from the Council.

After the Balloting Glasses had been duly closed, and the lists examined by the Scrutineers, the following gentlemen were declared to have been duly elected the Officers and Council for the ensuing year:—

OFFICERS.

PRESIDENT.

Sir Charles Lyell, F.R.S. and L.S.

VICE-PRESIDENTS.

Sir H. T. De la Beche, F.R.S. and L.S.
Prof. E. Forbes, F.R.S. and L.S.
D. Sharpe, Esq., F.L.S.
Sir R. I. Murchison, G.C.St.S., F.R.S. and L.S.

SECRETARIES.

William John Hamilton, Esq.
John Carrick Moore, Esq.

FOREIGN SECRETARY.

C. J. F. Bunbury, Esq., F.L.S.

TREASURER.

John Lewis Prevost, Esq.

COUNCIL.

Rev. P. B. Brodie, M.A.
C. J. F. Bunbury, Esq., F.L.S.
Charles Darwin, Esq., F.R.S.
Sir H. T. De la Beche, F.R.S. and L.S.
Sir P. G. Egerton, Bart., M.P., F.R.S.
Earl of Enniskillen, D.C.L., F.R.S.
Prof. E. Forbes, F.R.S. and L.S.
G. B. Greenough, Esq., F.R.S. and L.S.
William John Hamilton, Esq.
William Hopkins, Esq., M.A., F.R.S.
Leonard Horner, Esq., F.R.S. L. and E.
L. L. B. Ibbetson, Esq.
Sir Charles Lyell, F.R.S. and L.S.
G. A. Mantell, LL.D., F.R.S. and L.S.
John C. Moore, Esq.
Sir R. I. Murchison, G.C.St.S., F.R.S. and L.S.
The Right Rev. The Bishop of Oxford, F.R.S.
Lyon Playfair, M.D.
Samuel Peace Pratt, Esq., F.R.S. and L.S.
John Lewis Prevost, Esq.
Prof. A. C. Ramsay.
D. Sharpe, Esq., F.L.S.
S. V. Wood, Esq.

TRUST ACCOUNTS.

RECEIPTS.	£	s.	d.	£	s.	d.
Balance at Banker's, 1st of January 1849, on the Wollaston Donation Fund	61	14	6			
Belonging to Ordinary Account	0	6	0			
				61	8	6
Balance at Banker's, Geological Map Fund				11	5	0
Received on account of the Geological Map (sold)	20	10	0			
Dividends on the Donation Fund of 1084*l.* 1*s.* 1*d.* Red. 3 per Cents.	31	11	6			
				52	1	6
				£124	15	0

We have compared the books and vouchers presented to us with these statements and find them correct.

DANIEL SHARPE,
ALFRED TYLOR, } *Auditors.*

Jan. 30, 1850.

PAYMENTS.	£	s.	d.
Cost of chiselling out fossils from the Cape of Good Hope	2	15	0
Award to M. Alcide D'Orbigny	27	2	0
Award to Mr. W. Lonsdale	31	5	6
Cost of Engraving Palladium Medal awarded to Mr. Jos. Prestwich, Jun.	0	6	0
Paid on account of Geological Map:			
Mr. Greenough, balance of 1848	11	5	0
Balance at Banker's, Trust Account	52	1	6
	£124	15	0

VALUATION *of the Society's Property; 31st December*, 1849.

PROPERTY.	£	s.	d.	£	s.	d.
Due from Messrs. Longman and Co., on Journal, Vol. V.				50	15	9
Due for Authors' Corrections				17	5	0
Due for Subscriptions				18	18	0
Balance in Banker's hands				517	11	1
Balance in Clerk's hands				19	18	2
Funded Property, 3597*l.* 10*s.* 5*d.* Consols				3453	0	0
Arrears of Admission Fees (considered good)	39	18	0			
Arrears of Contributions prior to 1849, considered good	6	6	0			
Arrears of Contributions of 1849	31	10	0			
				77	14	0
				£4155	2	0

[*N.B. The value of the Mineral Collections, Library, Furniture, stock of unsold Transactions, Proceedings, Quarterly Journal and Library Catalogue is not here included.*]

Jan. 30, 1850. J. L. PREVOST, *Treasurer.*

DEBTS.	£	s.	d.
Due to Messrs R. and J. E. Taylor, on Journal, Vol. V	42	2	6
Balance in favour of the Society	4112	19	6
	£4155	2	0

Income and Expenditure during the

INCOME.

	£	s.	d.	£	s.	d.
Outstanding, 1848: Quarterly Journal, Vol. IV. (Messrs. Longman & Co.) paid June 8th				45	11	8
Balance at Banker's, January 1, 1849	483	17	6			
Balance Ditto (included in Trust Account)	0	6	0			
Balance in Clerk's hands	27	5	7			
				511	9	1
Composition received				31	10	0
Arrears of Admission Fees	10	10	0			
Arrears of Annual Contributions	34	13	0			
				45	3	0
Admission Fees of 1849				121	16	0
Annual Contributions of 1849				691	19	0
Dividends on 3 per cent. Consols				103	15	10
Sale of Transactions				21	15	0
Sale of Transactions in separate Memoirs				2	17	1
Sale of Proceedings				2	15	0
Journal, Vol. I., allowance on sale from the Publisher				0	10	0
Sale of Journal, Vol. II.				8	6	6
Sale of Journal, Vol. III.				9	1	6
Sale of Journal, Vol. IV.				25	19	6
Sale of Journal, Vol. V.				146	12	3
Sale of Library Catalogue				0	12	6

We have compared the Books and Vouchers presented to us with these Statements, and find them correct.

DANIEL SHARPE,
ALFRED TYLOR, } *Auditors.*

£1769 13 11

Jan. 30th, 1850.

Year ending December 31st, 1849.

EXPENDITURE.

	£	s.	d.	£	s.	d.
Outstanding, 1848:						
Quarterly Journal, Vol. IV. (Messrs. R. and J. E. Taylor)..				48	14	0
Quarterly Journal, Vol. IV. (Messrs. Reeve and Co.)				8	10	5
Compositions invested				31	10	0
General Expenditure:	£	s.	d.			
Taxes	35	6	4			
Fire Insurance	3	0	0			
House Repairs	32	9	6			
Furniture Repairs	13	7	6			
New Furniture	11	0	0			
Fuel.....	43	8	0			
Light	26	4	8			
Miscellaneous House Expenses, including Postages.....	47	2	7			
Stationery	17	8	2			
Miscellaneous Printing	35	18	0			
Tea for Meetings	26	17	0			
				292	1	9
Salaries and Wages:						
Assistant Secretary and Curator	163	6	8			
Clerk	100	0	0			
Porter	80	0	0			
House Maid	33	4	0			
Occasional Attendants	10	10	0			
Collector.....	24	11	6			
				411	12	2
Library				27	6	6
Museum.....				12	18	10
Diagrams at Meetings				12	15	6
Miscellaneous Scientific Expenses				4	8	8
Publications:						
Transactions	21	13	0			
Transactions, separate Memoirs	0	8	7			
Journal, Vol. II.....	0	12	4			
Journal, Vol. IV.	2	16	3			
Journal, Vol. V.....	356	6	8			
Proceedings	0	10	0			
				382	6	10
				1232	4	8
Balance at Banker's, Dec. 31, 1849....	517	11	1			
Balance in Clerk's hands	19	18	2			
				537	9	3
				£1769	13	11

ESTIMATES *for the Year* 1850.

INCOME EXPECTED.

	£	s.	d.
Account due by Messrs. Longman and Co. in June, on Quarterly Journal, Vol. V.	50	15	9
Account due by Author, for corrections in Quarterly Journal, Vol. V.	17	5	0
Due for Subscriptions on Quarterly Journal, Vol. V.	18	18	0
Arrears (See Valuation-sheet)	77	14	0
Ordinary Income for 1850 estimated:			
Annual Contributions (205 Fellows)	645	15	0
Admission Fees:			
Residents (6)	37	16	0
Non-residents (6)	63	0	0
	100	16	0
Dividends on 3 per Cent. Consols	103	15	10
Sale of Transactions, &c.	25	0	0
Sale of Quarterly Journal	210	0	0
	£1249	19	7

J. L. PREVOST, TREASURER.

Jan. 30, 1850.

EXPENDITURE ESTIMATED.

	£	s.	d.	£	s.	d.
Bill due to Messrs. R. and J. E. Taylor, on Journal, Vol. V.				42	2	6
General Expenditure:						
Taxes	35	1	4			
Fire Insurance	3	0	0			
House Repairs	15	0	0			
Furniture Repairs	15	0	0			
New Furniture	20	0	0			
Fuel	30	0	0			
Light	26	0	0			
Miscellaneous House Expenses	50	0	0			
Stationery	20	0	0			
Miscellaneous Printing	35	0	0			
Tea for Meetings	27	0	0			
				276	1	4
Salaries and Wages:						
Assistant Secretary	200	0	0			
Clerk	100	0	0			
Porter	80	0	0			
House Maid	33	4	0			
Occasional Attendants	10	10	0			
Collector	25	0	0			
				448	14	0
Library, Binding and Additions*				10	0	0
Museum				27	0	0
Diagrams at Meetings				13	0	0
Miscellaneous Scientific Expenditure				5	0	0
Publications, Quarterly Journal				400	0	0
„ Transactions				25	0	0
				1246	17	10
Probable surplus of Income				3	1	9
				£1249	19	7

* The sum of £50 voted in 1849 for the Library has not yet been expended.

PROCEEDINGS

AT THE

ANNUAL GENERAL MEETING,

15TH FEBRUARY, 1850.

AWARD OF THE WOLLASTON MEDAL AND DONATION FUND.

AFTER the Reports of the Council had been read, the President, Sir Charles Lyell, delivered the Wollaston Palladium Medal to Mr. William Hopkins, M.A., of St. Peter's College, Cambridge, addressing him as follows:—

MR. HOPKINS,—The Council have stated in their Report that they have awarded to you the Wollaston Medal of this year for your researches illustrative of the application of Mathematics and Physics to Geology.

On presenting to you this token of our esteem, I shall take the opportunity of mentioning more fully than the terms of the award could do, those works by which the Council are of opinion that you have earned a just title to this honour.

Your examination of the limestone district of Derbyshire is the earliest of your geological labours with which I am acquainted. By tracing out in detail the position of the associated beds of trap, provincially called toadstone, you obtained a clue to the structure of that region, and were thus made familiar with the general phænomena of elevation. The contemplation of these phænomena led you to conceive that all the complex effects of upheaval and dislocation might possibly be referred to a simple cause acting under determinate conditions, and that this cause might be an elevating force, such as the intumescence of a fluid mass beneath the solid crust operating simultaneously throughout the whole of a disturbed region. It was therefore by first observing in the field the facts to be accounted for, that you were enabled to reduce the problem to such a determinate form, as to bring it under the domain of accurate investigation. Your solution of this problem, contained in your researches on Physical Geology, was published in the Cambridge Transactions, and you endeavoured to show how the law of parallelism, so frequently seen in the anticlinal and synclinal folds of strata, might depend on simple mechanical principles.

In your paper on the Transport of Erratic Blocks, also printed in the Cambridge Transactions, you have estimated the force of great sea-waves of translation, such as might arise from a sudden upheaval of the bed of the ocean, and you have calculated the enormous rate of increase in the transporting power of currents, according to their increased velocity. I have elsewhere ventured to express my doubts whether such waves have really been the principal instruments which conveyed the huge boulders and erratics of the northern drift from place to place; but I hold that the value of such investigations as yours does not depend on the acceptance or rejection of the particular theories to which they may be immediately applied. They belong to a class of researches which must be gone into and worked out by mathematicians before we can pronounce positively on the sufficiency or insufficiency of many of the causes assigned to account for observed phænomena.

After you had discussed in your paper on Physical Geology the principles on which a theory of elevation might be founded, you proceeded to examine the Wealden and the Bas Boulonnais, in order to test your theoretical results by field observations. In a subsequent memoir on the Lake District of Cumberland, published by this Society, you pointed out that the valleys in which the lakes originated depend on a system of dislocations following a law in exact accordance with your theoretical deductions. In the same paper you have also given a series of diagrams, which exhibit with great clearness your conception of the different phases through which the geology and geography of the Lake district must have passed during the successive stages of its elevation and denudation.

Time will not permit me to give an analysis of your memoirs on the Mechanism of Glacial Motion, and on the Effects of the Internal Pressure and Tension of Rocks, considered as illustrative of cleavage. These subjects involve points of controversy on which philosophers of high authority are still at variance. But I cannot conclude without alluding to the most elaborate and difficult problem in which you have ever been engaged; I mean your attempt to determine whether the solid crust of the earth can be so thin as to justify the hypothesis, that volcanos are in immediate communication with a central fluid nucleus. In grappling with this abstruse question, you begin by reminding us, that if the earth were perfectly spherical, the axis about which it rotates would preserve, during its annual motion round the sun, a perfectly parallel position. But as the earth is spheroidal and not spherical, the attraction of the sun and moon on the protuberant equatorial portions destroys this

parallelism, and at the end of the year the inclination of the axis is not exactly as at the beginning. This produces a motion of the equinoxes of about fifty seconds annually in a direction contrary to the order of the signs of the zodiac. Previously to your researches, it had been proved that this motion might be exactly accounted for, by supposing the earth to have been primitively fluid, and to have at length become perfectly solid to its centre. But you have inquired whether the precession of the equinoxes would be such as it is observed to be, if the earth consisted of a solid shell covering an internal fluid nucleus. You point out that the mechanical action of the attractions of the sun and moon must, in that case, be entirely different from the case of a solid globe; and by your calculations we are taught, that if the crust were as thin as is supposed by many geologists, when they reason on the causes of volcanos, the precession would differ from its observed amount by a quantity which could not be mistaken. Hence you draw the important inference that the minimum thickness of the crust of the globe cannot be less than one-fourth or one-fifth of the earth's radius; that is to say, from 800 to 1000 miles. It is, I believe, generally felt by mathematicians, that a knowledge of the possible influence of great pressure in promoting solidification is a great desideratum, before we can carry out these speculations on the internal fluidity of the earth to their full extent; and we rejoice therefore to hear that you are now engaged in experiments which lead you to hope that you may be able ere long to supply this deficiency.

Mr. Hopkins said, in reply,—

I beg, Mr. President, to express my sense of the honour which the Council of the Geological Society has conferred on me by their award of the Medal which you have just presented to me. Few persons, I believe, can have entered on and prosecuted the study of geology impelled more than myself by a spontaneous love of the science. The investigations and speculations which it presents to us have always been in my estimation of especial interest; and if I had met with no reward besides the pleasure which has attended the prosecution of such researches, I should still have thought the time and labour I have devoted to them well bestowed. But, Sir, every one who has been long and earnestly engaged in any scientific inquiry, will be well aware how much gratification and encouragement we may derive from the sympathy of those who are fellow-labourers with us in the same field of investigation. The expression of this sympathy on the part of the Geological Society towards myself, in

this award of the Wollaston Medal, I feel to be one of the most gratifying compliments that could have been paid me by any body of scientific men; and in making this acknowledgement of the honour I have received, I would also state that I shall not regard this Medal merely as the reward of past labours, but shall also consider it (as such rewards ought, I conceive, to be considered) a powerful incitement to future exertion. Before I conclude, Mr. President, let me offer to yourself my best thanks for the manner in which you have spoken on this occasion of my geological researches, and for the clear and accurate outline which you have given of them.

The President then addressed Mr. Morris as follows:—

Mr. Morris,—The Council have this year awarded to you the balance of the proceeds of the Wollaston Fund, to assist you in the publication of the new edition of your 'Catalogue of British Fossils.' It is now seven years since the Council took an opportunity of paying you a similar compliment, to aid you in preparing your first edition of the same excellent work. They were then aware that your list of organic remains was not simply a compilation from other authors, but that you had devoted much time and thought to the examination of original specimens, and the comparison and identification of species. We now learn with pleasure that you expect to add nearly 1000 species to those previously enumerated as British fossils, and we hope that this award, however small a contribution towards the pecuniary outlay you have incurred, may act as an encouragement, by proving to you how highly this Society appreciates your services in the cause of palæontology.

Mr. Morris said, in reply,—

Sir,—I cannot but feel gratified at the compliment you have just paid me. Fully aware of the imperfect character of my 'Catalogue of Fossils,' I have endeavoured, as far as time would allow me, to improve the same, and in this respect have received the cordial assistance of many members of this Society. Besides which, the active labours of the Geological Survey, and the publications of the Palæontographical Society, have materially increased our knowledge of the extent and distribution of British fossils. I have thus been enabled to collect and examine many new facts, and the award that I have this day been honoured with will stimulate me to continue my researches. But I appreciate it still more, not only as an evidence of the kind interest with which the Council have viewed my past labours, but more especially as coming from yourself, Sir, whose

published works have constantly shown the important aid that geology has received from the cautious inductions derived from the study of palæontology.

After the other proceedings had been completed, and the Officers and Council had been elected, the President proceeded to address the Meeting.

ANNIVERSARY ADDRESS OF THE PRESIDENT,

SIR CHARLES LYELL.

Gentlemen,—You will have heard in the Report of your Council, that the finances of the Society continue to be in a flourishing state. In the course of the past year we have had to lament, as usual in so large a body, the death of several of our Members, and some of these it will be my duty more particularly to mention, as having distinguished themselves by original investigations, or by using the influence of their station or fortune in promoting the progress of Geology.

Christian VIII. King of Denmark was enrolled a Fellow of this Society in 1822. Two years before that time, when travelling in Italy, he had witnessed an eruption of Vesuvius, and had read a description of it to the Academy of Sciences at Naples; a communication published in their Transactions, and afterwards reprinted in Leonhard's Journal for 1822.

From an early age he had taken a lively interest in the progress of natural history, and when Crown Prince, formed at Copenhagen, at his own expense, a magnificent collection of shells, the number of species being estimated at not less than 12,000, exclusive of fossils. When I visited the Danish capital in 1835, he placed this museum and his library at my disposal, and I had then an opportunity of knowing that he kept up an acquaintance with the new species added from year to year to his cabinet, then in charge of an able conchologist, Dr. Beck, and that he was very desirous of making his museum useful to all zoologists. Nor was he inattentive to the points of controversy then agitated respecting the geology of Denmark. He

questioned me closely as to my opinion, whether the strata of Faxoe, containing certain species of *Cyprea*, *Oliva*, *Mitra*, and other genera usually regarded as characteristic of the tertiary period, really belonged to that epoch, or to the cretaceous rocks. That the latter conclusion was correct I had satisfied myself, after exploring the cliffs of Moën and Seeland, as I have explained in your Transactions; and you are aware that the Faxoe beds, together with those of Maestricht and Sezanne near Paris, have been recently classed as an upper member of the great cretaceous system*.

When Christian VIII. succeeded to the throne, the cares and duties of an absolute monarch did not make him forgetful of his former love for natural history. He was always accessible to scientific foreigners and natives, and set on foot several publications, among which I may mention the 'Gea Danica' of Professors Steenstrup and Forchhammer. He also gave his patronage to a splendid botanical work on the palms of Mexico, by Professor Liebmann, and promoted liberally the geological expedition of Baron Waltershausen and Professor Bunsen to Iceland. He also took care that a good naturalist should accompany the voyage of the Galathea round the world; and when that expedition returned, he directed that the valuable collections, made by the officers in various countries, should be divided equally between the Universities of Copenhagen and Kiel. As Crown Prince, he had been elected President of the Academy of Sciences at Copenhagen, and when he attended their meetings, after his accession to the throne, he always declined to be received as king, taking his place simply as a member, or as any other President. After a reign of nine years, he died in January 1848.

The Earl of Auckland is well known to have zealously used his influence in England, and the political power which for some years he wielded as Governor-General in India, in the encouragement of various branches of science and natural history. When the Directors of the East India Company determined in 1844 to send out a geologist to survey the coal-fields of Bengal, Madras, and other parts of their Eastern possessions, I was consulted by Lord Auckland, then lately returned from the East, in regard to the best mode of organizing the undertaking, and was struck with his earnestness in forward-

* Geol. Trans. 2nd series, vol. v. p. 249.

ing the objects in view. He was intimately acquainted with all that had been previously done, towards opening out the mineral resources of India; indeed several of the previous surveys had been set on foot by himself; and when explaining to me his views, he justly observed that a Government should limit itself to the task of collecting and publishing correct information, and giving a right direction to private enterprise, without attempting to derive pecuniary profits, from its undertakings.

Sir Edward Ryan has shown me a pamphlet, entitled "Hints for collecting information, compiled for the expedition to China," which was planned by Lord Auckland in 1840, and intended to direct the attention of the officers employed on that service to the acquisition of knowledge of various kinds, both relating to science and the arts of life, and the manners, customs and languages of the people whom they might visit. In these instructions we trace the germ and to a great extent the model of that Manual of Scientific Inquiry, for which, several years later, when he became First Lord of the Admiralty, Lord Auckland obtained the editorship of Sir John Herschel. Such of you as have studied this most useful Manual are aware how largely the Fellows of this Society have contributed to its contents; the geology having been written by Mr. Darwin, the mineralogy by Sir H. De la Beche, the geography by Mr. Hamilton, the memoir on earthquakes by Mr. Mallet, and the zoology by Prof. Owen.

William Clift, Esq., for many years Keeper of the Hunterian Museum of the College of Surgeons, served several times in the Council of this Society between the years 1832 and 1837. From an early period many of the ablest and most active members of the Society were in the habit of consulting him on all questions bearing on fossil osteology, and we find frequent acknowledgements of his valuable services in the papers of Dr. Buckland, Dr. Conybeare and others. Dr. Mantell also, in his first paper on the Iguanodon, published so long ago as 1825, says, "I resolved to avail myself of the offer of Mr. Clift, (to whose kindness and liberality I hold myself particularly indebted,) to assist me in comparing the fossil teeth with those of the recent Lacertæ in the Museum of the Royal College of Surgeons. The results of this examination proved highly satisfactory, for in an Iguana which Mr. Stutchbury had prepared to present to the College, we

discovered teeth possessing the form and structure of the fossil specimens."

Similar acknowledgements are made by the Dean of Westminster in his 'Reliquiæ Diluvianæ' (p. 35), and in his paper in our Transactions on the Pterodactyle (vol. iii. 1829); some of the minute particulars of the structure of that flying reptile having been illustrated by the drawings of Mr. Clift. The co-operation indeed of the Keeper of the Hunterian Collection is noticed in almost every memoir descriptive of fossil bones which appeared after the date of Sir Everard Home's first paper on the Ichthyosaurus in 1814, down to the period when Prof. Owen began to relieve his father-in-law from his duties as Curator of the Museum. Nor were the fruits of his skill and industry confined to British publications, for not a few of the figures in the 'Ossemens Fossiles' of Cuvier were executed by the same hand, and the great French anatomist often speaks of them in flattering terms, as "faites par Mons. Clift, dont le beau talent a déjà enrichi ce recueil de tant de planches non moins remarquables par leur exécution que par leur fidélité."

The first of Mr. Clift's own memoirs on organic remains was a description of "Some Fossil Bones discovered in Caverns in the Limestone Quarries of Oreston," printed in the Philosophical Transactions for 1823. His first contribution to the Geological Society was, "An Account of two new species of Mastodon and other Fossil Vertebrata, discovered by Mr. Crawfurd in Ava*." His second and last paper read to the Society was, "An Account of the Megatherium brought home in 1832 by Sir Woodbine Parish from South America†." Valuable as are these works, they convey no idea of the extent and variety of his labours in fossil osteology; for, regardless of personal distinction, he was singularly indifferent whether the results of his original research were given to the world in publications of his own or in those of his friends. He united a deep and tranquil enthusiasm for philosophical pursuits to great independence of character and simplicity of mind and manners, and he never seemed to need any other stimulus to excite or sustain his intellectual exertions than such as were afforded by the love of inquiry or the delight of arriving at new truths.

* Geol. Trans., 2nd ser. vol. ii. 1828. † Ibid. vol. iii.

Frederick Dixon, Esq. was educated at Eton, and completed his professional studies as a surgeon under Sir Astley Cooper. From the esteem in which his personal character, abilities and studious habits were held by his teachers and fellow-pupils, there is little doubt that his professional career would have been successful had he devoted himself to metropolitan practice. But he preferred the enjoyments and greater leisure afforded by a country residence, and retired early to reside on some property which he possessed at Worthing. There he continued to practise up to the period of his fatal illness in September last. His early tastes and habits of observation led him to study the geology and to collect the fossils of parts of Sussex adjacent to his residence; and the peculiar skill with which he worked out organic remains from their native matrix, made his collection remarkable for the rarity, beauty and perfect condition of the specimens, especially of those from the chalk-pits of the Vale of Arun, and from the eocene beds of Bracklesham.

The number of new facts thus brought to light by Mr. Dixon determined him to publish a volume on the cretaceous and tertiary formations of Sussex, illustrated by figures of undescribed fossils, executed by the best artists whose skill he could command. He had made considerable progress in the preparation of this work at the period of his decease; but as an author he was known only by a few papers on the historical antiquities of his neighbourhood, published in the Journal of the Sussex Archæological Society.

In the determination of his own rare and unique specimens of organic remains, he was so fortunate as to obtain the assistance of the highest authorities in different departments of palæontology; and the appendix to his projected work was designed to contain a description of the fossil reptiles and mammals by Professor Owen; of the fossil fishes by Sir Philip Egerton; of the echinoderms and crustacea by Professor Edward Forbes; of the fossil shells by Mr. Sowerby; and of the fossil corals by Mr. Lonsdale: Mr. Dixon reserved to himself an account of the geological structure of his county, and of the localities of his fossil specimens, with other circumstances connected with their discovery. He expended large sums on the beautiful plates engraved for this publication, and you will learn with pleasure that Prof. Owen has most liberally undertaken to complete and publish this posthumous work. Mr. Dixon died at the age of

fifty, on the 27th of September, 1849, deeply regretted by all those who knew him*.

Gentlemen,—It is now my duty, in accordance with the usual custom of my predecessors in office, to say something of the scientific labours of geologists during the past session. It is nearly twenty years since I announced, in the first edition of my 'Principles of Geology,' the conviction at which I had then arrived, after devoting some time to observation in the field, and to the study of the works of earlier writers, that the existing causes of change in the animate and inanimate world might be similar, not only in kind, but in degree, to those which have prevailed during many successive modifications of the earth's crust. I attempted to adapt the views which Hutton and Playfair had first promulgated, to a more advanced state of our science, and to extend their application, by showing, that should the same causes continue to act with unabated energy, for indefinite periods of the future, they must bring about revolutions not inferior in magnitude to those recorded in the monuments of past ages. After an interval of twenty years, during which Geology has been enriched by a vast accession of new facts, and when so many powerful minds, in every civilized country, have brought their intellectual energies to bear on the philosophy of our science, I may I think affirm that the idea of comparing the modern agents of change with those of remote epochs, as not inferior in power and intensity, appears even to the most sceptical a far less visionary and extravagant hypothesis than when I first declared my belief in its truth. As, however, there are not a few original observers, whose opinion I respect, who are still opposed to this doctrine, I cannot I believe do better on the present occasion than take a brief view of the bearing of some leading discoveries of modern date on this much-controverted question. I adopt this course the more willingly, because a perusal of the memoirs read before the Society during the past session, and the contemporary publications of other scientific bodies and authors in Europe and America, has convinced me that they are so varied and so overwhelming by their number and importance, as to make it impossible, within the limits of this anniversary Address, to give an analysis of the contents of each, still less

* A fuller account of Mr. Dixon's labours will be found in the 'Medical Times' for Dec. 8, 1849, of which notice I have largely availed myself.

to add criticisms and comments of my own. But in order to keep myself still further within due bounds, I shall not enter at present the field of palæontology, reserving for a future opportunity a comparison of the organic creation, in ancient and modern times, and the question whether the fluctuations of the living inhabitants of the globe have been regulated formerly by the same laws as now.

Among the points of geological interest relating exclusively to the inanimate world, none have given rise to a greater difference of opinion than the various causes suggested to account for the position of stratified and unstratified rocks in mountain chains. They are usually referred to the development of mechanical and volcanic forces of a paroxysmal character; but geologists who favour these views are by no means agreed whether the causes thus capable of modifying the earth's crust, were all of them in the beginning in a state of the highest intensity, and afterwards declined in energy, or whether they have been exerted again and again during short intervals of violent convulsion followed by long periods of repose. On these, and questions of a kindred nature, I shall proceed to offer some observations, well aware that I shall advocate opinions which I have long cherished, and on which I can scarcely fail to have a strong bias, but reminding you at the same time that they who defend conclusions opposed to mine have equal reason to doubt their own impartiality, and to suspect that they also may be influenced by old associations, and those strong prepossessions, with which nearly all the early literature of our science is imbued. It may be true that no geologist worthy of the name would contend at this time of day for the modern origin of our planet, or maintain the doctrine that it was created contemporaneously with man, although the multitude, including many of the educated classes, may, in their ignorance of the records of creation as written in the heavens and the earth, still fondly cling to such opinions. The cultivators of our science may be ready to grant the most indefinite duration to each successive geological epoch, yet they may still unconsciously derive a love of cataclysms and catastrophes, and faith in a primæval chaos out of which the present order of things was evolved, from an hereditary creed, not founded on facts, or strict inductive reasoning on natural phænomena.

As introductory to this subject, I cannot do better than recall your attention to the recently published memoir of Sir Roderick Murchi-

son, on the structure of the Alps, Apennines and Carpathians, which deservedly occupies an entire Number of your Quarterly Journal*. It comprises a masterly summary of the labours of those who had gone before him, in a very difficult field of inquiry, as well as a luminous account of his own personal investigations, and should be studied by every one who is desirous of knowing what point the modern progress of geology has reached. On various important questions of which he treats, and in which I entirely agree with him, I cannot enter at present, but there is one leading conclusion established in his memoir which bears specially on the theory selected for discussion in this Address. He proves, as it appears to me in a satisfactory manner, that those stupendous movements to which the loftiest chain in Europe owes its complicated structure, and by which its component strata have been dislocated, fractured and contorted, belong to a very modern æra in the earth's history. In the long calendar of geological events, the Eocene period is the first which presents us with a fossil flora and fauna, both terrestrial and aquatic, of a very complete character, comprising mammalia both of the sea and land, of all the principal classes, now contemporary with man. It would doubtless be rash to assume that no plants or animals of equally high organization may not have pre-existed on this globe, for the recent progress of discovery in our science puts us on our guard against founding hasty generalizations on mere negative evidence. The fossil skeletons of saurians discovered in the coal-measures of Saarbrück near Treves are still fresh in our recollection, as are those footprints of the same age first detected by Dr. King, and which I have myself examined at Greensburg in Pennsylvania. We are waiting also with impatience for more minute details respecting some reptilian footprints of a still more ancient date, found by Mr. Isaac Lea in the old red sandstone at Pottsville, near Philadelphia; nor have we forgotten the tracks of numerous birds, observed in the red shales and sandstones of Connecticut, of a date nearly bordering on palæozoic times. Such facts, like the unexpected discovery of the Stonesfield marsupials, a quarter of a century ago, warn us against the presumption of taking for granted, that our present knowledge of the earliest occurrence of a particular class of fossils in stratified rocks, can be reasoned upon as if it afforded a true indication of the first appearance of a particular class of beings on the globe.

* Vol. v. Part i. 1848, December.

Nevertheless, with every reservation for the future enlargement of our ideas respecting the comparative perfection of the living creation in our own times and in the remoter ages, we may at least assert, that in the present state of our science the eocene fauna and flora may be contrasted with those of older date, in regard to the more complete manner in which they represent the animal and vegetable creation.

In the chronological classification of the materials composing the crust of the earth, it has been often asked, whether we ought to ascribe to the older tertiary epoch, or to the cretaceous system, the great nummulitic formation of the Alps, and other parts of Europe. This much-controverted question,—one, as I shall presently point out, of the highest theoretical interest, in reference to the hypothesis of the unabated intensity of the existing agents of change,—was declared by M. Boué, some years ago, to be the great problem of the day, and Sir R. Murchison has therefore devoted to its consideration a large portion of his memoir. M. Boué indeed announced in 1847 his own conviction that the nummulitic rocks belonged to the eocene or lower tertiary period, and remarked, in a paper read to the French Geological Society in that year, how much delight Alexander Brongniart would have experienced, had he lived to see one of his boldest and most startling generalizations thus crowned with success*. Al. Brongniart had in fact declared many years before, that the shells of the summit of the Diablerets, one of the loftiest of the Swiss Alps, which rises more than 10,000 feet above the sea, were referable to species characteristic of the eocene strata of the neighbourhood of Paris. He only felt considerable hesitation, he said, in assigning to them so modern a date, because the overlying limestones were so compact and homogeneous as to agree in lithological character with much older secondary rocks.

Several of the most animated discussions which have taken place in this room since 1825, have turned, as you will recollect, on this subject, especially when the fossil shells brought by Mr. Pratt from Biaritz in the Pyrenees were laid upon our table. A decided opinion was then expressed by many of us that the nummulitic series of that southern chain must be referred to the lower part of the eocene group, as it was made clear that the proportion of fossil species common to the Biaritz beds and the chalk was extremely small—

* Bulletin, vol. v. 2nd Series, pp. 69, 71.

much too few to imply a cretaceous age for the strata in question, or even a zoological passage from the cretaceous to the tertiary formations. They who have read with care the successive numbers of the 'Bulletin' of the Geological Society of France, are aware how much that body has been occupied with the same problem, and how steadily the evidence in favour of the same important conclusion has been gaining strength. M. d'Archiac, writing in 1847 on the fine collection of Biaritz shells submitted to his inspection by Mr. Pratt, observed that forty-eight, or one-fourth of the whole series, were identical with fossils of the lower eocene of the Paris basin, while the rest were all tertiary forms except four, which belonged to species of the chalk*. In a paper by M. Deshayes, read to the Geological Society of France in June 1844†, that able conchologist declared, after examining the Biaritz fossils, "that the whole of the nummulitic system must be classed as tertiary; an opinion confirmatory," he said, "of the results previously arrived at by M. Leymerie in the Corbières, and of M. Bertrand Geslin in the Alps." Lastly, I may observe, that you will find similar opinions recorded in the 'Bulletin,' either in the memoirs or verbal comments of MM. Deshayes, Charles Desmoulins, Raulin, Leymerie, Tallavigne, Delbos, Desor, Boué, Archiac, and Alcide D'Orbigny, all published in the course of the last six years. Whether a real transition from the cretaceous to the tertiary strata can be made out, is a point which has also been fully discussed, and how far the Maestricht beds are represented in the Pyrenees. It appears from the researches of MM. Desmoulins and Raulin, that some few of the characteristic fossils of Maestricht have really been found in that chain; but you will, I think, agree with M. Deshayes, that they are not enough to establish the existence of any true equivalent of the Maestricht group—that distinct and uppermost division of the chalk to which the Faxoe coralline limestone in Seeland, as well as the pisolitic strata of Sezanne near Paris, are referable.

When we consider that the age of the nummulitic formation of the Pyrenees, however clearly it may now be determined to be tertiary, has been regarded by so many able authorities as a subject of perplexity and debate up to so late a period, we cannot feel surprised that

* Bulletin, vol. iv. 2nd Series, p. 1006.

† Translated in Quart. Journ. Geol. Soc. 1845, p. 111.

MM. De Beaumont and Dufrénoy, in constructing their geological map of France many years before, should have referred these strata in the Alps, and in the regions bordering the Mediterranean, to an age anterior to the calcaire grossier of Paris, especially when we learn that even now M. Agassiz affirms, that out of 139 species of echinoderms described by him from the nummulitic beds of the Mediterranean, one species only is common to them and the calcaire grossier. The same geologist maintains that all the fish of Glarus and Monte Bolca, which according to the latest opinions must be classed as eocene, differ entirely from those of Sheppey *. Yet I am by no means disposed to question, on the ground of this want of agreement in the ichthyolites, that the Glarus slates are in truth tertiary, still less to doubt that the limestone of Monte Bolca belongs to the same period: I have always regarded the latter as eocene from the time when I visited that locality in company with Sir Roderick Murchison in 1828. You have seen also, in the classification of the three successive eocene formations established by Mr. Prestwich for the older tertiary deposits of Great Britain, that while each division is characterized by its peculiar assemblage of shells, a part only of the species pass from one division to another, and that the specific difference of the mammalia belonging to each division, and still more of the first, as determined by Agassiz, is extremely marked.

The researches, above alluded to, of Sir Roderick Murchison in the Alps in 1847, and the palæontological evidence of various eminent writers brought together by him in illustration of his views, have, I think, shown unequivocally, that, together with the nummulitic limestone, an enormous thickness of overlying strata of dark-coloured slates, marls, and fucoidal sandstones, provincially called Flysch, are separable from the cretaceous system of Northern Europe, and must also be regarded as lower eocene. His attempt however to make out a passage from the tertiary to the secondary series by means of an intervening group of marls, green sandstone and impure limestone, appears to me to be far less successful, since a true representative of the Maestricht beds is wanting in the Alps, or is very ill-defined, and no other equivalent assemblage of organic remains is enumerated sufficiently rich in forms, or intermediate in character, to fill up the wide gap between the eocene strata and the chalk.

* Bulletin, vol. v. pp. 414, 415.

I have dwelt thus at length on the age of the nummulitic series, because its recognition as a tertiary deposit draws with it consequences of the utmost theoretical importance, and is singularly confirmatory of a remark made by M. Desnoyers many years ago in his address to the French Geological Society, namely, "that the more the Alps are studied the younger they grow." This saying was elicited by the admission by competent observers, that certain schistose rocks of great thickness, containing dark writing slates, originally classed as "transition formations" by some of the followers of Werner, and regarded as of palæozoic age, were really secondary. Now we are called upon to go much further; for these same strata belong to the flysch, and therefore constitute what is by no means the base of the eocene system. To the English geologist who is old enough to remember when all the soft clays and loose sands overlying the chalk, some of them containing shells of species identical with those now living, were looked upon as very modern, and as the creations of yesterday, in comparison with the rocks of the higher Alps, it may well appear a startling proposition to learn that the clay of London was in the course of accumulation as marine mud at a time when the ocean still rolled its waves over the space now occupied by some of the loftiest Alpine summits. It will follow, moreover, as a corollary from the same data, as before hinted, that not only the upheaval of the Alps, but all the principal internal movements, dislocations, inversions and contortions of the strata, are subsequent to the origin of the nummulitic deposits, and had not therefore even commenced till great numbers of the eocene vertebrate and invertebrate animals had lived and died in succession.

If the development of so vast an aggregate amount of dynamical agency in times so modern in the earth's history had been confined to a single narrow zone of mountains, it would be a fact of no small significance as invalidating all theories which ascribe such magnificent displays of mechanical force to very remote epochs. But on extending our survey, we find some of the members of this nummulitic series, with their characteristic fossils, playing the same part in the Pyrenees, Apennines and Carpathians, and spreading over a large part of the globe of which the geology is best known. They are met with in full force in the north of Africa, as for example in Algeria and Morocco; they have been traced from Egypt into Asia Minor,

and across Persia by Bagdad to the banks of the Indus. They occur not only in Cutch, but in the mountain-ranges which separate Sinde from Persia, and which form the passes leading to Cabul. They have been followed still further eastward into India, and may be said to enter bodily into the structure of all the continental lands and mountain-chains of the Old World.

Were we to endeavour to estimate the changes in physical geography which can be proved by the position of these marine eocene strata to have occurred since the commencement of the tertiary period, we should find them to be very inadequately expressed by stating that they equal in amount the conversion of sea into land of a continent as large and lofty as that of Europe, Asia, and the north of Africa. I endeavoured in 1834, in a map constructed for the 3rd edition of my 'Principles of Geology,' to show the extent of surface in Europe and part of Asia which had been covered by water, at some time or other, since the beginning of the eocene period. But, had I been then aware that a true pictorial representation of such modern revolutions in physical geography would have required the submergence of the Alps, Pyrenees, Apennines and Carpathians, and the insertion of a few insignificant islands only in their place, I might have thought such an illustration superfluous or without meaning, and have been satisfied by simply insisting on the post-eocene ubiquity of the ocean—not indeed by a simultaneous, but by a successive occupancy of the whole ground. But how small a portion even of the superficial remodeling of the earth's crust in recent times is expressed, by declaring that we can establish by direct proof or legitimate inference the upheaval out of the sea of all the land in Europe, Asia, and part of Africa! During the same tertiary periods there have been vertical subsidences as well as elevations of the same areas; and we have every reason to believe that the larger part of the globe (comprising nearly three-fourths of its superficies), which is covered by water, has undergone, in equal periods of time, oscillations of level not inferior in degree to those to which the continental spaces have been subjected. If therefore we were to confine our thoughts to the mere outward modifications in the shape of the land or bed of the sea, and all the changes of climate and fluctuations in organic life inseparably connected with movements which have amounted, in some cases, to more than two miles vertically in one direction, besides

the lateral displacement of rocks and their denudation by water, the series of events would seem endless, and their magnitude not easily to be exaggerated. But it is evident that these superficial mutations are trifling in amount in comparison with revolutions which must have been going on simultaneously in the inferior parts of the earth's crust. The reality of these changes is certain, although their nature may be obscure; for we can rarely catch even a glimpse of the subterranean products of the eocene, miocene and pliocene epochs, because it requires far more time than the tertiary periods have as yet furnished, to allow the disturbing causes to uplift, depress, and rend open, or for the ocean to denude the incumbent rocks so as to make it possible for an inhabitant of the surface to behold them and appreciate their magnitude.

The Alps indeed, where the convulsions have been greatest, reveal to us some monuments of the vast chemical changes and re-arrangement of the component elements of rocks which have taken place since the deposition of the eocene strata, and we thus gain some insight into the nature of the transformation of mineral masses which must have been going on contemporaneously at greater depths. It appears, for example, that in some places granite has been intruded into the axis of the Alpine chain, and that in other places various granitiform compounds have been formed since the whole nummulitic formation was elaborated beneath the sea. "In passing," says Sir R. Murchison, "from east to west, from the Austrian into the Savoy Alps, the zone of metamorphism widens laterally, from the centre to the flanks of the chain, so as to affect even the younger secondary deposits, and in one or more tracts even the tertiary, some of the strata called flysch being converted into a crystalline state*." Instances are also adduced in the Bernese Alps (by the same author) of bands of granite or granitic schists in the midst of the flysch, demonstrating that the action of heat and vapours, or the causes commonly called plutonic, have changed even these modern deposits into gneiss, as well as into quartz rock and mica schist†.

To whatever geological period we may be disposed to assign the first origin or crystallization of the talcose granite and gneiss of Mont Blanc and other parts of the central nucleus of the Alps, we cannot doubt that they broke through the crust and were protruded into

* Quart. Journ. of Geol. Soc. vol. v. p. 164. † Ibid. vol. v. p. 213.

the atmosphere, or were laid bare by denudation, after the nummulitic limestone was formed, and consequently after the beginning of the eocene period. For my own part, I have little doubt that these granites are all tertiary, and that they may even have passed from a fluid or semi-fluid state to their present form at an epoch more modern than the eocene period. But although it is only in a few narrow strips of country, like the Central Alps, that nature discloses to us some of the nether-formed rocks of such modern geological æras, we cannot doubt that still greater modifications of the interior have extended downwards for many miles or leagues in depth beneath the Alps, and beneath every region, whether of land or sea, which has risen, sunk, or oscillated in level since the fossil shells and zoophytes of the lower eocene period were living in the sea. The imagination of the geologist strives in vain to form a just conception of the extent of these internal modifications of the crust, of which we are only beginning to interpret the outward signs. How much fracture and dislocation of solid rock must have taken place! how much heating and cooling, expansion and contraction, drying and baking, softening and re-solidifying of sedimentary strata! Over how vast an area, and to how great a depth, often hundreds of yards or several miles beneath the surface, have mineral masses been injected by lava, or dissolved by thermal waters, or corroded by acids, or permeated by steam, or impregnated with magnesia, sulphuric acid, or other substances introduced in a gaseous form! What obliteration has there not been of organic remains, and of the signs of stratification, in the course of the tertiary ages which have elapsed since the nummulitic strata and incumbent fucoid grits lay submerged beneath the ocean!

Sir Roderick Murchison has given a graphic description of the foldings, so sharp and so often repeated, of a grand succession of sedimentary strata in the Alps. Among other examples, he has cited one case of extraordinary inversion of large masses in the canton of Glarus, examined by himself and M. Escher, where a limestone of the Jurassic period containing ammonites is, on the one hand, "overlaid by a zone of talc and mica schist, having in parts quite the aspect of a primary rock;" while in another direction it is continuously superimposed for miles on beds of highly inclined flysch of eocene age*.

* Quart. Journ. of Geol. Soc. vol. v. p. 246.

It seems that in the course of the stupendous movements which have raised these modern beds to the height of 8000 feet above the sea, and caused portions of them to become crystalline or metamorphic, large masses of the solid Jurassic limestones of the Oxfordian age have been pushed bodily out of their place, and planted unconformably on the edges of strata of the nummulitic series. Our indefatigable colleague naturally shrinks from offering any explanation of so marvellous and anomalous a state of things, extending as it does over a considerable area. In attempting to estimate such gigantic movements, the powers of imagination, he says, are at fault; and "surely," he adds, "it is not unphilosophical to believe that in those days the crust of the earth was affected by forces of infinitely greater intensity than those which now prevail." In particular, he regards the apparent inversion of the tertiary molasse along the flanks of the Alps, and its great elevation, as "a clear demonstration of a sudden operation or catastrophe*."

Now, I shall first venture to remark, in regard to these theoretical views, that the Alps, when considered as a mountain-chain which has originated entirely since the commencement of the tertiary period, bear emphatic and irrefragable testimony to the fact, that the intensity of the causes which have disturbed the crust of the globe has not diminished in the tertiary as compared to the secondary or primary fossiliferous epochs. It may possibly be still contended, that the energy and violence of the movements were more general in those earlier epochs, supposed by some to have been close upon the confines of "the reign of Chaos and Old Night;" but it cannot be pretended that there are any proofs of a more magnificent development of the disturbing forces in any given region of equal extent, and accomplished in an equal lapse of time, at any period antecedent to the upheaval of the Alps. If, however, any one should maintain, that in the earlier ages the movements which upheave, depress and derange the position of strata were more general, and that they agitated simultaneously much wider horizontal areas, it will be easy to adduce the most overpowering evidence to the contrary. The wide extent in the United States of America, and in parts of Russia, of Carboniferous, Devonian and Silurian strata, which although upraised above the sea, continue almost as level as when the beds were first thrown

* Quart. Journ. of Geol. Soc. vol. v. p. 258.

down beneath its waters, clearly demonstrates the limitation of the agency to which great foldings and contortions of stratified rocks have been due to very confined spaces in each epoch. Were it otherwise, the multiplication of such extensive convulsions during a long succession of ages would have made it impossible to find any spot on the globe where the oldest rocks had escaped extreme derangement. It only remains therefore for the advocates of the paroxysmal hypothesis to assert that, although the disturbing forces have by no means grown feebler in the modern or tertiary times, as compared to periods when the oldest of the known strata were deposited, yet there have been brief æras of convulsion on a very grand scale, when the ordinary repose of nature was violently interrupted in particular regions (as in the Alps, for example) in a manner wholly different, in regard to the magnitude of the effects produced, from any which we have witnessed in historical times, or which ever occurred formerly during the ordinary and normal state of the globe.

That doctrines of this kind are popular, I am well aware; and if you desire to know how many modern writers have declared in their favour, I refer you to the excellent work which has just been published by one of our foreign members, M. d'Archiac, on 'The History of the Progress of Geology from the years 1834 to 1845.' He has executed conscientiously nearly half of the laborious and delicate task assigned to him by the Geological Society of France, and has given us a faithful digest of memoirs written in a variety of languages and scattered through the Proceedings and Transactions of numerous scientific bodies, or the periodical magazines and journals of almost every civilized country. A geologist of practical experience in the field, as well as of extensive erudition, was required to make a good classification of such complex materials, and justly to appreciate their relative value. In M. d'Archiac's pages every author of merit has been allowed an impartial hearing, and the expositor's own occasional criticisms are not obtruded too prominently on the reader's attention; when they are offered, they are so judicious as to aid us materially in understanding the faithful analysis he has given of the opinions of others. In the concluding part of his chapter on "Le terrain moderne," and when speaking of active volcanos, and in other places, he stoutly denies the adequacy of the causes which have modified the earth's crust in historical times to produce effects such as may enable

us to explain geological monuments. "We must have recourse," he says, "to other causes, both organic and inorganic, of a more energetic and even paroxysmal character*."

On this subject I must make two preliminary remarks: First, that our present inability to decipher some of the monuments of past ages by a key derived from the effects of causes now acting, ought never to be adduced as an argument of much weight in favour of the paroxysmal theory; for it might with equal or greater propriety be urged as a reason for believing in the adequacy of existing causes, or their identity with those of former times, since no one doubts that we are ignorant of the nature of many subterranean and suboceanic changes now in progress. If therefore there was nothing obscure or mysterious in geological phænomena, if they simply presented to us a picture of objects as familiar as the lavas of Vesuvius or the calcareous tufas of mineral springs, or the newly-formed deposits of a delta seen at low water, we should be entitled to suspect a great want of analogy between the ancient and modern processes at work above and below the earth's surface. We should then be entitled to ask, where are the nether-formed and deep-sea formations of the olden time? Where are the signs of those changes brought about in the bowels of the earth corresponding to such as are now in progress in regions inaccessible to human observation? Why have not the causes which have upheaved mountains and deeply fissured the rocks, or which have denuded large areas, revealed to us ancient stratified and unstratified rocks, wholly distinct from any which we now see generated by ordinary volcanic action or formed in lakes and shallow seas. Secondly, it should be thoroughly understood that the decision of the question at issue can in nowise be determined by simply comparing the magnitude of the changes brought about in historical times with those of antecedent periods. It may be safely affirmed, that the quantity of igneous and aqueous action,—of volcanic eruption and denudation,—of subterranean movement and sedimentary deposition,—not only of past ages, but of one geological epoch, or even the fraction of an epoch, has exceeded immeasurably all the fluctuations of the inorganic world which have been witnessed by man. But we have still to inquire whether the time to which each chapter or page or paragraph of the earth's autobiography refers, was not equally

* Archiac, Hist. des Progrès, &c. tome i. pp. 209, 670.

immense when contrasted with a brief æra of 3000 or 5000 years. The real point on which the whole controversy turns, is the relative amount of work done by mechanical force in given quantities of time, past and present. Before we can determine the relative intensity of the force employed, we must have some fixed standard by which to measure the time expended in its development at two distinct periods. Dr. Whewell has justly observed, that "mechanical power retains its amount, however much it be distributed through time and divested of the character of extraordinary violence*,"—a principle which should never be lost sight of when we contrast the effects of the historical with those of antecedent epochs. It is not the magnitude of the effects, however gigantic their proportions, which can inform us in the slightest degree whether the operation was sudden or gradual, insensible or paroxysmal. It must be shown that a slow process could never in any series of ages give rise to the same results.

The advocate of paroxysmal energy might assume an uniform and fixed rate of variation in times past and present for the animate world that is to say, for the dying-out and coming-in of species, and then endeavour to prove that the changes of the inanimate world have not gone on in a corresponding ratio. But the adoption of such a standard of comparison would lead, I suspect, to a theory by no means favourable to the pristine intensity of natural causes. That the present state of the organic world is not stationary can, I think, be fairly inferred from the fact, that some species are known to have become extinct in the course even of the last three centuries, and that the exterminating causes always in activity, both on the land and in the waters, are very numerous; also, because man himself is an extremely modern creation; and we may therefore reasonably suppose that some of the mammalia now contemporary with man, as well as a variety of species of inferior classes, may have been recently introduced into the earth, to supply the places of plants and animals which have from time to time disappeared. But granting that some such secular variation in the zoological and botanical worlds is going on, and is by no means wholly inappreciable to the naturalist, still it is certainly far less manifest than the revolution always in progress in the inorganic world. Every year some volcanic eruptions take

* Quart. Journ. Geol. Soc. vol. iii. p. 231.

place, and a rude estimate might be made of the number of cubic feet of lava and scoriæ poured or cast out of various craters. The amount of mud and sand deposited in deltas, and the advance of new land upon the sea, or the annual retreat of wasting sea-cliffs, are changes the minimum amount of which might be roughly estimated. The quantity of land raised above or depressed below the level of the sea might also be computed, and the change arising from such movements in a century might be conjectured. Suppose the average rise of the land in some parts of Scandinavia be five feet in a hundred years, the present sea-coast might be uplifted 700 feet in fourteen thousand years; but we should have no reason to anticipate, from any zoological data hitherto acquired, that the molluscous fauna of the northern seas would in that lapse of years undergo any sensible amount of variation. If a botanist were asked how many earthquakes and volcanic eruptions might be expected, and how much the relative level of land and sea might be altered, or how far the principal deltas will encroach upon the ocean, or sea-cliffs recede from the present shores, before the species of European forest-trees die out, he would reply that such alterations in the inanimate world might be multiplied indefinitely before he should have reason to anticipate, by reference to any known data, that the existing species of trees in our forests would disappear and give place to others. In a word, the movement of the inorganic world is obvious and palpable, and might be likened to the minute-hand of a clock, the progress of which can be seen and heard, whereas the fluctuations of the living creation are nearly invisible, and resemble the motion of the hour-hand of a time-piece. It is only by watching it attentively for some time, and comparing its relative position after an interval, that we can prove the reality of its motion. If therefore in the coal-measures of South Wales or Nova Scotia we find the same fossil trees repeated through a mass of strata formed in shallow water 10,000 feet thick, we ought not to feel surprised, but merely conclude that formerly, as now, the rate of change in the vegetable kingdom was extremely slow, so that a stupendous mass of stratified sand and mud, as well as great revolutions in physical geography, might be slowly effected, without there being time for any important fluctuation to be brought about in the species of plants inhabiting the globe.

I have endeavoured to show in my 'Second Visit to the United

States*,' that a great oscillation of level has taken place in the valley of the Mississippi and its tributaries, by means, first, of a slow downward movement, and then of an ascending one, and that the whole was accomplished since the period when the freshwater and land-shells now inhabiting that great valley were already in existence. We ought not therefore to be surprised when we discover sea-beaches in Norway 700 feet high, in which the shells are identical with those now inhabiting the German Ocean; for we have already seen that the rise of land in Scandinavia, however insensible to the inhabitants, is rapid when compared to the rate of contemporaneous change in the testaceous fauna. Were we to wait therefore until the mollusca shall have undergone as much fluctuation as they underwent between the period of the liassic and upper oolite formations, or still more between the oolite and chalk, or between the Wealden and eocene strata, what stupendous revolutions in physical geography ought we not to expect, and how many mountain-chains might not be produced by the repetition of shocks of moderate violence, or by movements not even perceptible by man! I may take this opportunity of stating, in reference to the permanent effects of subterranean movements in our times, that in all likelihood we are always in danger of underrating their intensity, because we can only measure their amount on the sea-coast, whereas the adjoining mountain-chains seem generally to be more shaken by earthquakes, and probably undergo a greater change of level than the low countries.

Let us now return to the Alps, and inquire whether geologists who ascribe their origin to paroxysmal forces have been able of late years to bring to light any new facts in support of their favourite doctrine. On the contrary, if I mistake not, they have been more and more compelled to assign the time during which the disturbing power was exerted to a succession of distinct geological periods, in some of which the force must have operated very slowly, while in other cases where it was sudden it may probably have been intermittent, and consisted, as in ordinary volcanic action, of a repetition of shocks or explosions of moderate intensity. In illustration of these principles, I may first mention that some of the volcanic eruptions of the Alps, which produced the porphyry called melaphyre, broke out again and

* Vol. ii. chap. xxxiv.

again, as M. Favre has demonstrated, in the sea of the Jurassic period, and they were accompanied and followed by metamorphic action, occasioned by gaseous emanations. The tuffs and trap dikes of Monte Bolca and the Vicentine show that other volcanic eruptions poured out lava and ejected scoriæ into the waters of the eocene sea. Again, after this period, the protrusion, if not the formation, of the talcose granite, or protogene of the central nucleus of the Alps, occurred. The upheaval of nearly the whole mountain mass, from the waters of the eocene sea to an elevation of more than two miles above its level, happened subsequently to the deposition of all the nummulitic beds and the flysch. These latter deposits, thousands of feet in thickness, shared, after the commencement of the tertiary period, in all the movements, whether slow or convulsive, to which the Alpine rocks owe their curvatures, dislocations, and vertical or lateral displacement. The grand sinking-down of the nagelflue or conglomerate of the molasse, more than a mile vertically, belongs again to a still later period, which did not begin till all the eocene movements had terminated, and was due to a gradual subsidence along the whole northern flank of the chain. At a still more modern æra, the entire upheaval of the same molasse took place, so that it reached at length its present altitude of 3000 or 4000 feet above the sea. Nor did the uplifting agency cease here, for it continued till the newer or subapennine tertiary beds were made to emerge. There are proofs indeed of the relative level of sea and land having been modified even after the erratic blocks were conveyed to their present sites, or subsequently to the glacial period of Northern Europe.

This assignment to a great number of distinct and separate periods of the work done by the moving and disturbing powers, is by no means the result of the study of the Alps exclusively. In other mountain-ranges it is now ascertained that the upheaving and depressing forces have been propagated in succession along the same parallel zones of country; and M. Élie de Beaumont has frankly confessed that he was in error when he first pronounced the Pyrenees to be a chain due to a single upthrow, "un seul jet," or "une chaîne élevée en une seule fois." He and M. Dufrénoy now go so far as to agree with M. Durocher, that in the Pyrenean chain, in spite of the general unity and simplicity of its structure, six, if not seven systems

of dislocation, each chronologically distinct from the other, can be made out*.

In regard to the Alps, it appears from the observations of Leopold Von Buch, Sir Roderick Murchison, and others, that whatever be the major axis of the crystalline mass in the centre, such also is the prevailing direction of all the sedimentary deposits which lie on either side of the chain. Whether the axis be composed of granite, syenite, gneiss, mica-schist, marble, dolomite, or of any rock formed by eruption or by the metamorphism of pre-existing strata, there is obviously some connection between the position of the central crystalline nucleus and the dominant strike of the flanking deposits. It is as if the intrusion of the igneous matter at certain periods had not only raised the chain, but so injected and distended its central parts, as to force outwards the pliant strata on each side, and to cause them to fold themselves into parallel anticlinal and synclinal flexures.

The theory first proposed by Von Buch, of the conversion of mountain masses in the Tyrol and other parts of the Alps into dolomite, and of other limestones into gypsum, has been gradually embraced by the majority of the most eminent geologists who have carefully examined the great chain. The porous and cavernous nature of the dolomite are referred to by MM. É. de Beaumont and Morlot as a character implying the alteration of a compact rock into one of more open texture which had been permeated by gases†. "It is now more than twenty years," says De Beaumont, writing in 1847, "since I first advocated Leopold Von Buch's views, who attributed the gypsums and dolomites of the Alps to *épigénie*, or to the alterations of calcareous masses by mineral springs and gaseous emanations which came up from the interior of the earth at the time when the porphyries called melaphyre were formed‡. M. Frapolli, in reference to similar metamorphic action, has adduced numerous facts illustrative of the manner in which carbonates of lime may have been turned by sulphurous vapours into gypsum; and Sir R. Murchison reminds us that the well-known thermal waters of Aix do now actually change the ordinary Jurassic limestone into sulphate of lime; while, according to M. Coquand, another example of the like metamor-

* Bulletin, 2nd Series, vol. iv. p. 1368.

† Ibid. vol. vi. p. 318.

‡ Ibid. vol. iv. p. 1282.

phism is afforded by Mofettes, where the sulphuro-hydrous emanations turn the cretaceous limestone into gypsum along the lines of fissure which they permeate*. M. Favre, as before stated, has shown that the period when the porphyries called melaphyre were erupted agrees well with this hypothesis, and that the heat and gases disengaged during such volcanic outbursts might well have transformed the calcareous into magnesian rocks. Thus it is supposed that the carbonate of lime containing shells of the Jurassic epoch has been slowly transformed into magnesian carbonate, and perhaps an increase of volume was gradually acquired by the gypseous and dolomitic masses in proportion as they derived fresh accessions of mineral matter from below. If so it may have caused expansion, and have furnished an irresistible lateral pressure.

If in the central parts of the Alps we suppose heat to have accompanied the metamorphic action which has converted into gneiss and mica-schist, not only the Jurassic and cretaceous, but even certain eocene strata, this same heat must have caused many kinds of rock to expand, and might, in this manner, slowly give rise to the sideway thrust exhibited in the curved beds on either flank of the chain. It is now known that granite and sandstone, while solid, expand and contract, even under such a range of atmospheric temperature as the difference of a Canadian winter and summer produce. We must also take into account that highly inclined or vertical argillaceous strata, such as the flysch, would shrink when heated, and give off their water; while other rocks, ranged side by side, might be simultaneously expanding or partially melting, so as to occupy more room, and that the clays might thus be pressed into solid shales and acquire irregular and complicated curves. The irregularity and confusion would be greatly increased by local variations in the composition of the stratified deposits, whether in the direction of their strike or dip, and also by the unequal intensity of the heating and cooling processes, whether the central be compared with the lateral parts of the chain, or the superficial with the internal parts. Yet we cannot feel sure, that were such mighty changes now in progress in any range of mountains subject to earthquakes, such as the Andes or Himalaya, we could guess at the direction of the movement, for the contraction or expansion of mineral masses might be carried on as

* Bulletin, 2nd Series, vol. vi. p. 124.

slowly as the growth of a tree or the swelling of its roots in the soil.

M. de Beaumont, in his essay on volcanic and metalliferous emanations*, observes that, according to the experiments of Deville, the contraction of granite in passing from a melted or plastic to a solid state must be more than ten per cent. We have here then at our command an abundant source of depression on a grand scale at every geological period in which granitic rocks have originated. All mineralogists seem agreed that the passage from a liquid or pasty to a solid and crystalline state cannot, in such cases, have been instantaneous throughout voluminous masses; yet by suddenly crystallizing alone could it have given rise to the paroxysmal downthrow of overlying rocks. On the contrary, every hypothesis seems to proceed on the assumption that the crystallization of granite was an extremely gradual process. Many very instructive speculations on this head will be found in the writings of Scheerer, Frapolli, Fournet, Durocher, De Beaumont, and others, who have attempted to explain the reciprocal penetration of the crystals of quartz and felspar which enter into the composition of granites. These minerals, as is well known, have crystallized in an order independent of their relative fusibility, the quartz not only imprinting its form on the felspar, but sometimes itself receiving the imprint of the crystals of felspar. Gaudin and Fournet, in order to account for this fact, have shown that dissolved flint may cool without solidifying, and remain in a gelatinous state, and thus crystallize after the felspar and mica; while M. de Beaumont has suggested that electric action may prolong the duration of the viscosity of silex †.

The conglomerate of the molasse called nagelflue, before alluded to, and referred to the miocene, if not in part at least to a still later (pliocene) date, attains in some places a truly wonderful thickness, exceeding 6000 and even 8000 feet. It is very conspicuous in the Rigi and in the neighbourhood of Lucerne, as well as in the Speer near Wesen. The lower part of the group, containing terrestrial plants, fluviatile shells, and the bones of extinct land-quadrupeds, is considered by M. Escher as a freshwater formation, while some of the sandstones and marls of the upper members of the series contain

* Bulletin de la Soc. Géol. 2nd Series, vol. iv. p. 1312.

† Bulletin, 2nd Series, vol. iv. p. 1022.

marine shells*. To explain the origin of such a succession of pebbly strata, we are naturally referred, by Studer, Escher, Sir R. Murchison, and others, to a long-continued depression along the whole external northern face of the Alps. Numerous torrents are supposed to have issued from the islands which then occupied the site of the loftiest portions of the chain, and the continuity of the strata is explained by imagining them to have accumulated on a shelving shore like that of the present maritime Alps. At first the materials must have been arranged in beds which sloped away from their parent rocks of the Alps; yet after sinking successively to enormous depths, they have been brought up again, so as to dip towards the older rocks, as if they passed under them.

The first part of this grand subsidence of the sea-bottom was doubtless analogous to that now in progress on part of the coast of Greenland. But if the adjoining land participated in the same downward movement, it is difficult to conceive how it escaped being submerged, or how it could continue to retain its size and altitude so as to continue to be the source of such an inexhaustible supply of pebbles. We can scarcely avoid speculating on a contemporaneous slow upheaval of the mountains. There may have been an ascending movement in one region, and a descending one in a contiguous parallel zone of country, as the northern part of Scandinavia is now rising while the southern portion in Scania is sinking, or at least has sunk within the historical period. Perhaps the not uncommon occurrence, of deep sea in the immediate vicinity of bold coasts and mountain-chains, may be connected with extensive lines of fault, parallel to the shores, on the opposite sides of which, vertical movements may be taking place in contrary directions, or one side may be motionless, while the other is subsiding. In no other way does it seem possible to account for the proximity, throughout a long series of ages, of high land, and of a sea-bottom always going down so gradually as to remain for a long time the receptacle of annual tributes of rolled pebbles, and acquiring in the end a thickness of 5000 and 8000 feet. In regard to faults which have shifted rocks several thousand feet in a vertical direction, it is often too hastily assumed that they must have been produced suddenly; whereas the reverse is indicated by the fact that the walls of such faults are rubbed, polished and striated, as if they had been

* Murchison, ibid. p. 229.

subjected to friction long continued or many times repeated. The mass moreover of fragmentary matter usually included between the opposite walls of such rents is partly reduced to fine clay or dust, and partly filled with stones which have been superficially scored in various directions.

The minute study of the structure and organic contents of strata of various ages, has made us of late years more and more familiar with the hypothesis of a slow sinking of the ancient floor of the ocean going on while it was receiving repeated accessions of sediment. We must not forget that in all such cases a solid foundation of subjacent rock of unknown depth, and perhaps much older than the newly superimposed deposit, is undergoing simultaneously a change of position, and that rocks still lower are undergoing, whether by cooling or crystallizing, a change of structure. These very gradual movements are quite as remarkable in the palæozoic as in the tertiary periods. By consulting the 'Memoirs of the Geological Survey of Great Britain,' you will learn that in Wales, and the contiguous parts of England, a maximum thickness of 32,000 feet (more than six miles), of carboniferous, Devonian and Silurian beds, has been measured, the whole formed whilst the bed of the sea was continuously and tranquilly subsiding. In illustration of a movement of the same kind, I need scarcely remind you of the coal-measures of South Wales, with their numerous under-clays, each containing Stigmaria, a phænomenon to which Mr. Logan first drew our attention. Mr. Binney of Manchester has since proved to us that all these Stigmariæ, found in the floor of every coal-seam, are the roots *in situ* of fossil trees, chiefly of the genus *Sigillaria*, and that they are occasionally attached to their stems or trunks,—a conclusion fully confirmed by the more recent observations of Mr. Richard Brown on the coal-fields of Nova Scotia. Sir Henry De la Beche also, in his paper on the rocks of South Wales and the South-west of England, confirms these statements, and shows that subsidences of vast amount took place slowly during the accumulation of the palæozoic strata, the sea all the while remaining shallow, in spite of a depression of one or two miles. Still later, Professor John Phillips, in the second volume of the same 'Survey,' has pointed out analogous phænomena in the old red sandstone of the Forest of Dean; and these strata, 7000 feet thick, are described as having been formed in a sea of moderate depth. Fossil corals and shells imbedded

as they grew, or ripple-marked sandstones and sandy or gravelly strata with subordinate diagonal layers, confirm these views. Such movements took place contemporaneously with the growth of organic matter, just as subsidence on a grand scale is now going on over vast areas in the Pacific and Indian Oceans,—a class of facts on which Mr. Darwin has founded his theory of atolls, or the origin of annular coral islands with lagoons. His theory, as you have probably observed, has been recently embraced and more fully elucidated by Mr. Dana, in his valuable chapters on the geology of the American Exploring Expedition under Capt. Wilkes.

The investigations of Professor Edward Forbes, on the laws governing the distribution of marine animal life, at various depths in the Mediterranean, have powerfully aided us in determining the conditions under which particular strata were formed, the depth of water being deducible from a careful study of the organic contents of each bed. Availing themselves of this key, Captain Ibbetson and Professor Forbes have shown how the lower cretaceous strata of the Isle of Wight have been deposited on a gradually sinking submarine bottom, while Mr. Prestwich has applied the same method of reasoning, with equal success, to the eocene strata of Alum and Whitecliff Bays in the same island*. In this instance it is remarkable, that after a depression of 1800 feet very slowly effected, there was still contiguous land inhabited by the Palæothere of Binstead and Hordwell and its contemporaries, as well as a freshwater estuary, implying that the movements in different parts of that region were either very unequal or opposite, or that they consisted of great oscillations of level. It would be easy to cite a variety of continental authorities in support of the same principle, but enough has been stated to entitle me to ask, whether the subsidence of mountainous masses, lying immediately beneath the floor of the ocean, brought about by such slow degrees, can possibly occur, without causing beneath many of the sunk areas, vast flexures of the strata, which as they sink for miles vertically must occasionally be forced to pack themselves into smaller spaces than those which they previously occupied. If this be true, the contortions and foldings of pliant beds, and the fracture and dislocation of the more unyielding rocks, have frequently been due to movements as gradual as those of various ages to which I have been alluding.

* Prestwich, Quart. Journ. Geol. Soc. vol. ii. p. 223.

The imagination may well recoil from the vain effort of conceiving a succession of years sufficiently vast to allow of the accomplishment of contortions and inversions of stratified masses like those of the higher Alps; but its powers are equally incapable of comprehending the time required for grinding down the pebbles of a conglomerate 8000 feet in thickness. In this case, however, there is no mode of evading the obvious conclusion, since every pebble tells its own tale. Stupendous as is the aggregate result, there is no escape from the necessity of assuming a lapse of time sufficiently enormous to allow of so tedious an operation. No intervention of a cataclysm or series of paroxysmal waves can avail us; and if the geologist could abridge the period, he would find that far from being a gainer, he had deprived himself of the only means ever yet suggested of explaining another set of geological monuments, relating to what we term denudation. It is not simply by fixed and permanent inequalities of level, in the land and sea, or by the alternation of dry and rainy seasons, or of summer heat and winter's frost, that the aqueous action of torrents, rivers, breakers, tides and currents acquires a sustained energy, capable of denuding wide areas, but by the gradual elevation or subsidence of continents and islands, occasionally accompanied by many minor oscillations of level. It is by reiterated slight variations in the position of a coast line, by the continual shifting of the points of attack, that every portion of the surface of the land is exposed by turns to denudation, and is prevented from ever settling into a state of equilibrium and cessation from waste. If earthquakes agitate the country from time to time, while it is rising or sinking, so as to block up valleys and cause temporary lakes and fissures, or the fall of river-cliffs and sea-cliffs, the power of aqueous destruction will be still further augmented.

In the first volume of the 'Memoirs of the Survey of Great Britain,' Professor Ramsay has shown that the missing beds, removed from the summit of the Mendips, must have been nearly a mile in thickness, and he has pointed out considerable areas in South Wales and some of the adjacent counties of England, where a series of palæozoic strata not less than 11,000 feet in thickness have been stripped off. All these materials have of course been transported to new regions; and when it is shown by observations in the same 'Survey' that the palæozoic strata are from 20,000 to 30,000 feet thick, we have a counterpart of older date of denuding operations on a scale of similar

grandeur, for what has been carried away or borrowed from one space must always have been given to another. The gain must always have equalled the loss, and sediment deposited in one area must be the measure of the quantity of pre-existing rock cleared away elsewhere. The announcement of this principle may seem, perhaps, like insisting on a truism, but I find it necessary, because in many geological speculations I observe it is taken for granted that the external crust of the earth has been always growing thicker, in consequence of the accumulation of stratified rocks, as if they (and possibly the contemporaneous rocks of fusion, in progress far below) were not produced at the expense of pre-existing rocks, stratified and unstratified. Whether indeed the trap and granite of successive ages were formed by the melting of matter previously solidified, will be questioned by those who contend that the globe was originally a fused mass, and who also assume (still more gratuitously as appears to me) that geological monuments have reference to the period when the melted nucleus was passing to a more and more solid state. But even those geologists must admit that strata of the old red sandstone, or of any other ancient or modern rock of mechanical origin, imply the transportation from some other region, whether contiguous or remote, of an equal amount of solid material, so that the stony exterior of the planet has always grown thinner in one place whenever by accessions of new strata it has acquired density in another. The vacant space left by the missing rocks, after extensive denudation, may be less imposing to the imagination than a vast thickness of conglomerate or sandstone, or the bodily presence as it were of a mountain-chain, with all its inclined and curved strata; but the denuded tracts speak a clear and emphatic language to our reason, and like mountain masses of fossil nummulites, or of corals and shells, or seams of coal based on under-clays full of Stigmaria and surmounted by erect fossil trees, demand countless ages for their origin, and these ages supply the time in which continents and mountain-chains may rise and sink, without sudden, instantaneous or paroxysmal action.

I have already alluded to the slow crystallization and consequent contraction of granitic mixtures, and to the expansion of solid rocks by heat, and to the melting of stony masses, together with various metamorphic agencies, as the causes of slow and gradual movement, both vertical and horizontal. Formerly, when the stratified materials

of the Alps presented to the eye of every observer a confused heap of ruin, before any general laws governing the lines of longitudinal fracture, or the parallel foldings of the strata, were caught sight of, it might be argued, that such chaotic disorder implied one or more paroxysmal outbursts of subterranean force, wholly different from ordinary volcanic or any other known agency. But Sir Roderick Murchison agrees with an eminent foreign member of this Society, Professor H. D. Rogers of the United States, and with several Swiss geologists of distinction, that the dislocations and lateral movements of Alpine strata have been obviously regulated by general movements, in which system and law can be discovered. Mr. Rogers, you will remember, declared in this room, when describing the structure of the Alps and Jura, that he recognized a striking analogy between the form of the flexures discernible in these European chains and those observed by him and his brother in the Appalachians of North America. In both cases the successive parallel folds have on one side a steep, short dip, while the other side of the anticlinal flexure is longer and less inclined. This longer side, in the Appalachians or Alleghanies, dips towards the belt of intrusive volcanic rocks on the south-east flank of the chain. So in the Alps, the steep, short dips do not face the crystalline nucleus, but the longer and less inclined ones, except where a curve has been so great that the whole are made to dip one way, the more steeply inclined side having become as it were more than vertical.

In the Alps, the anticlinal folds, where they are greatest, dip inwardly towards the central peaks, and therefore in opposite directions on each flank of the chain. In the Jura, the steep, sharp dips of each parallel fold are upon the side, facing the Alps, and hence Professor Rogers imagines that the subterranean undulations in the earth's crust, which, according to his theory, gave rise to these flexures, were propagated, not from the Alps, but from the district of the Vosges, or the country towards the north-west. To this theory Professor A. Guyot strongly objects, arguing that it is more probable, on the contrary, that the immediate cause of the uplifting of the Jura is to be sought in the upheaval of the Alps. "The elevation," he remarks, "of the anticlinal ridges of the Jura diminishes gradually and regularly in proportion as the Jura recedes from the Alps, the summits sinking from 5000 to 2000 feet. The minor chains also of

which the system of the Jura is composed are not exactly in the direction of the system itself, but oblique in such a manner as to be parallel with the chain of the Alps." There is in fact an intimate relation between the two chains, and M. Guyot conceives that the movement has been the result of a contraction of the terrestrial surface in consequence of gradual cooling, and that the folding has been due to lateral pressure resulting from this contraction.

It is not my purpose to enlarge at present on the rival theories thus brought forward to solve a most difficult problem; and I confess myself unable at present to understand how, according to the hypothesis of Mr. Rogers, the grand flexures of the strata in mountain-chains can bear any intimate relation to great waves propagated through a subjacent reservoir of fluid matter. But if M. Guyot be correct in contending that a sinking-down of strata by gravity, owing to a slow contraction of part of the earth's crust below, can explain the flexures, we have then a cause introduced which might act as insensibly as the failure of support, so often witnessed in mines, especially after the removal of seams of coal. Such failure gives rise to what the miners call "creeps," which clearly prove that the sharpest bends and curvatures of yielding strata may be brought about by imperceptible degrees. Even if such an hypothesis be entitled, on pure mechanical principles, to equal favour, it should be preferred to one which appeals to extraordinary violence, for it must then be admitted that the "*dignus vindice nodus*" has not yet occurred.

I have already suggested that the talcose or protogene granites of the Alps may belong to the tertiary period. M. de Beaumont believes that they were not protruded into the atmosphere till they had already reached the region of perpetual snow. Whether there may be good grounds for such an opinion or not, it does not appear to me to follow that such granites may not have been solidified at a considerable depth in the bowels of the earth. No sufficient reason seems to have been advanced to prove that they ought to be regarded, as the French geologist seems to infer, almost as superficial products*. The limestones, sandstones and shales of the nummulitic and flysch series are of such enormous thickness, that tertiary granites may well be supposed to have crystallized beneath them, and then to have been exposed to view by breaking forth or bursting through

* Bulletin, 2nd Series, vol. iv. p. 1299.

the covering of sedimentary matter in the course of the enormous change of position which the Alpine eocene rocks have undergone. The question is one of the highest importance, because the French academician contends, that all the granites erupted in the earlier periods of the earth's history differed from those of later date, in being much more quartziferous; and he controverts the doctrine proposed by me in my 'Elements of Geology,' that the difference of mineral composition in the oldest rocks of this class now visible may reasonably and naturally be explained by imagining them to have originated at a great depth below the surface. On the contrary, M. de Beaumont supposes that granitic rocks charged with an excess of siliceous acid were formed at the surface in the older times, and he has even had the courage to present us with a diagram of Chaos, entitled "Chaos primitif," representing a scene by no means rude and disorderly, but where we behold two pyramidal mountains, from one of which the ordinary volcanic lavas and more volatile substances, such as sulphur, chlorine and aqueous vapour, are evolved; while from the summit of the other, granitic compounds, tin, fluor, and the more refractory and less volatile materials, are discharged*. It is suggested that the greater part of the metals which usually accompany tin were concentrated in the first envelope of the globe, but after the palæozoic epoch they were withdrawn from circulation, and like the primitive granites ceased to be emitted from the interior. The gases and vapours, from which the more ancient metalliferous compounds were sublimed, would, it is said, have been most deleterious to organic beings living in the air and ocean, so that their evolution in the sea and atmosphere in later times was discontinued.

For my own part, after having given the most patient consideration to these views, I see no sufficient grounds for believing that the same granitiform mixtures and metalliferous emanations may not have been disengaged in equal quantity at every successive geological period down to the most modern. We are taught by the activity of several hundred volcanos, that there must now be lakes and seas of melted matter in the interior of the earth, in every state, from one of perfect fusion to one of incipient crystallization; and as solid rock must thus frequently originate in great masses, under conditions different from that of lava poured out into the atmosphere, why should

* Bulletin, 2nd Series, vol. iv. p. 1322.

we not adopt as the most probable conjecture the idea that this matter is now, as of old, passing into granite, or into some of the granitiform compounds, more especially when we know that silex abounds in many modern lavas, and that certain obsidians and pumice do not differ materially in their component elements from granite.

I fully assent to the doctrine so ably advocated by M. É. de Beaumont, that a large class of metalliferous veins may simply be regarded as extinct mineral springs. They are fissures in which vapours, or thermal waters charged with various elementary bodies, have precipitated the materials of a refractory kind, or those which are the least easily retained in solution. The marked agreement between the contents of mineral springs and the emanations from active volcanos strongly supports this view. But why should we doubt that fissures now existing in solid rocks may in like manner communicate at one extremity with subterranean masses of fused matter, while at their upper end they terminate in mineral springs? and if so, why may not hot steam and gases and mineral waters be depositing at this moment, as actively as ever, that class of elementary bodies, whether metalliferous or not, which we find in the oldest veins? The steam or hot water will always part with these substances in the deeper parts of every fissure, and merely bring up to the surface the residuary salts which are more soluble and volatile. Hence mineral veins are marked by the habitual absence of alkalies, which are so readily dissolved in water.

When we consider the grand and reiterated movements of elevation and depression which have agitated the earth's crust since the palæozoic epoch, and the vast amount of volcanic action which can be shown to have been of subsequent date, it is evident that all those refractory bodies, said to have been "withdrawn from circulation," must have been from time to time re-melted, and therefore re-issued from the grand subterranean mint. Their circulation may always be confined to the interior of the earth, and they may never, except in very minute quantities, be disengaged superficially. If it be so, they must always be ancient in all future systems of geological classification; not because they originated at remote æras, but because time is required to uplift and expose them to view.

No illusion indeed is more likely to mislead us in our chronological speculations than the temptation to ascribe to antiquity appear-

ances which are in reality characteristic of a deep subterranean or submarine origin. Volcanic rocks now forming at a certain distance below the surface, or sedimentary strata which are in progress in deep seas, can very rarely emerge and become visible to man till they have acquired a high antiquity relatively to most of the lavas and beds of mud, sand and pebbles which will be formed in the interval of time between the origin of such subterranean or submarine rocks and their exposure above ground. They cannot, except in a few very disturbed regions, like the Alps, emerge from the sea, or break out in the centre of a mountain-chain, till a series of grand revolutions of the earth's crust has occurred throughout many large areas. Lofty cones of lava and scoriæ will have been piled up, old rocks will have been denuded or displaced, bent or fractured, and new strata, thousands of feet thick, will have been formed, besides the occurrence of several important fluctuations in the organic world, before the nether-formed products of fire or water are brought into view. Whenever these do appear, their aspect will be strange and unfamiliar to human observers, such as might well belong to bodies formed in a part of the great laboratory of nature, to which man has no access. Such singularity in outward form and internal texture will naturally be referred to an origin connected with the beginning of things, if the mind be already prepossessed with a belief that we are studying the monuments of a planet, which has been passing from a chaotic or nascent state to one of order and maturity, especially if the peculiar rocks in question are found invariably to have claims to a high relative antiquity.

"Granitic eruptions," says M. de Beaumont, "have become more rare in the more recent epochs*;" and doubtless it is most true, that in the newer secondary and older tertiary formations, the granitic rocks become more and more exceptional; but had we lived in the carboniferous or Permian epochs, we might, I conceive, with equal justice have declared the only granites then visible to be extremely ancient. The more quartziferous varieties, together with a certain class of metalliferous veins, posterior in date to the vegetation of the coal period, such as are now known to the miners of Cornwall, or to those of the Ural Mountains, would then have been unformed, or at least invisible. The ages which have elapsed since the coal-measures

* Bulletin, 2nd Series, vol. iv. p. 1299.

were accumulated are so countless, as to have afforded ample time for the upheaval of much crystalline rock and metallic ores from great depths, and for the clearing away of superficial matter by aqueous denudation. To what an extent this subsequent denudation has been carried may be shown by adverting to the fact, that the masses removed must have more than equalled in volume all the sedimentary strata newer than the coal, for some part of the materials of such strata have been more than once ground down into sand or mud since that period and re-stratified.

Before concluding I shall say a few words on another very different topic, yet one which has a distinct bearing on the theoretical question discussed in this Address. Until the transporting power of glaciers and icebergs was better understood, no geological phænomena were oftener appealed to in support of violent earthquake-waves, sudden deluges, rapid and overwhelming currents of mud, and other extraordinary agencies, than the northern and Alpine erratics scattered over hill and dale, and having no obvious relation in their geographical distribution to the present drainage or physical outline of the countries where they abound. The hypothesis which has recently gained more and more favour, as best explaining the dispersion of such blocks, dispenses with all sudden and paroxysmal exertion of force; nay, more, it does not even call into play a succession of waves such as ordinary earthquakes can produce. The rate at which huge blocks of stone travel for centuries on the surface of a glacier, never halting day or night, summer or winter, appears rarely to exceed, according to the exact measurements of Professor James Forbes, half an inch per hour. When the icy mass, with its moraine and included boulders, reaches the sea, and becoming detached on the coast, gives birth to an iceberg, the frozen raft traverses wide spaces of the ocean at the rate of a few miles a day, so that its advance is usually inappreciable by human sight. I have seen hundreds of these floating bergs at once in the Atlantic on their way southwards; but no observer could determine their direction, or decide whether they were aground or in motion, unless he had opportunities of comparing their relative position from day to day. So large is the volume of ice submerged beneath the water, that the waves and swell of the Atlantic during a storm have no more power to communicate a rocking motion to one of them than if they were islands, or parts of the firm land.

Should geologists ever be convinced that some of the most gigantic curvatures of Alpine strata have been the result of intense pressure, so moderated in its application as to have been just sufficient to overcome the resistance opposed to it,—should any of them ever declare their belief that the motion had been as insensible as the unfolding of the petals of a flower,—it would not imply a more remarkable revolution in popular opinion than we have witnessed in reference to the glacial hypothesis. Nor even then might we be entitled to pronounce the process a slow one relatively to other natural operations, organic and inorganic, which were simultaneously in progress. In the fourth volume of our Quarterly Journal (p. 70), Mr. Hopkins, to whom you have this year awarded the Wollaston Medal, has published an excellent paper on the elevation and denudation of the Lake district of Cumberland and Westmoreland. He has undertaken, and, as it appears to me, with no small success, the very difficult task of restoring, in a series of diagrams, the successive steps by which the physical geography of the country attained its present condition, although the changes to be accounted for, consisting of the addition of several new sedimentary formations, and repeated alterations of level, and denudation of rocks, were numerous and complicated. In one part of his memoir he has suggested the possibility of the period during which the dispersion of erratic blocks took place, having extended far back in geological time, even as far as the oolitic period; an opinion which is, I think, at variance with a great weight of evidence derived from the study of the boulder formation both in Europe and North America. But in regard to the mode of transport, Mr. Hopkins has taught us, that if the bed of the sea were suddenly uplifted from 100 to 200 feet in vertical height, such an instantaneous upward movement would give rise to currents having a velocity of twenty-five to thirty miles an hour, and these currents might move blocks of great magnitude from place to place. Thus a current of ten miles an hour would be capable of propelling a block of five tons weight, and its force increasing in the ratio of the square of its velocity, a current of twenty miles an hour would move a block of 320 tons. The experiments of Mr. Scott Russell on the velocity of waves of translation, although made with much smaller waves, are supposed to bear out these views*.

* Hopkins, Quart. Journ. Geol. Soc. of Lond. vol. iv. p. 70, No. 13.

Now, adopting all the mathematical and hydrostatical calculations of Mr. Hopkins as correct, they prove, I think, the non-occurrence or extreme rarity in past times of earthquake-shocks more violent than such as we have experienced in the last ten centuries. For when we consider how many marine formations have been upraised, some of them from seas of considerable depth, and what a vast amount of upheaval and subsidence, estimated, as I have already reminded you, by miles vertically, has taken place, it seems clear that if currents and waves of such power as those contemplated by Mr. Hopkins had really been set in motion, there would have been erratic blocks in deposits of all ages, instead of their being confined to the close of the tertiary period. Had these mighty waves swept again and again over the floor of the ocean, and over the land in ancient periods, a drift or boulder clay with rounded and angular blocks would have been conspicuous in the Eocene, Cretaceous, Jurassic, Triassic, Permian, Carboniferous, Devonian and Silurian formations, and would have been most strikingly displayed in such of these epochs as have been of the longest duration. I have seen fragments of gneiss eight feet in diameter in the base of the Silurian series in Canada, in the group called by the New York geologists the Potsdam sandstone*; but I observed in the same place similar gneiss *in situ*, in the immediate vicinity, so that the blocks may have been detached from an undermined cliff of the Silurian sea-coast. In like manner, in the valley of the Bormida, in Piedmont, there are huge rounded masses of serpentine in the tertiary molasse; but similar rocks *in situ* pre-existed in the same region, so that blocks may have been derived from the destruction of cliffs close at hand. In Scotland, also, we see occasional fragments of large dimensions in the conglomerates of the old red sandstone, especially on the western coast, but in that case there is no ground for presuming distant transport. In no part of the geological series, except in that of very modern date, do we find an extensive deposit of drift, like that spread over Northern Europe and North America.

It may doubtless be objected, that by adopting the glacial hypothesis we concede the possibility of one natural agent, such as frost, acquiring at certain periods an intensity of action far greater than at others, and hence I may be asked, whether the energy of any other cause may not in an equal degree be subject to secular variation? I admit

* See Travels in North America, vol. ii. p. 126.

the force of the argument, if not pushed beyond its legitimate bounds. No one can contemplate future changes in physical geography without foreseeing that the varying altitude and extent of polar and equatorial lands may give rise to an intensity of solar heat or glacial cold, such as is not experienced now, and may never have been experienced on the earth; for the combinations of circumstances on which the climate of the globe most depend are so varied, that no one can define or guess how far heat, cold, moisture, and other conditions, may deviate from a mean state of things in the course of ages. But speculations of this kind belong equally to the future, the past and the present, and imply no inconstancy in the general condition of our planet, such as is assumed in the hypothesis of its passage from a chaotic to a fixed, stable and perfect state. Living as we do in an æra which has immediately followed the glacial epoch, we are able to comprehend the state of the northern hemisphere in European latitudes, when cold like that of the arctic and antarctic circles extended further from the poles towards the equator. We may also reason philosophically on the state of the globe during the carboniferous epoch, when there may have been little or no ice even at the poles. We may conclude that in those days a warmer, damper, and more uniform climate prevailed, when the Sigillaria, Lepidodendron, Caulopteris, Calamite, and other fossil plants flourished, and when there were reefs of coral in the adjoining seas. Such organic remains may betoken, as our Foreign Secretary, Mr. Bunbury, has argued, rather the absence of frost than, as many botanists once thought, an intense tropical heat. M. Adolphe Brongniart, in his admirable Essay on the genera of Fossil Plants, published in the year 1849*, has questioned, and apparently with reason, the proofs hitherto adduced in favour of the existence of any true palms in the coal-measures, and Mr. Bunbury considers their absence as affording an additional argument to that derived from the universal preponderance of ferns in favour of a mild temperature in the atmosphere,—a warm, moist and uniform climate, not a tropical one. The flora, he says, of the London clay was of a much more tropical character. In this manner we may now reason philosophically on the remote carboniferous æra according to strict rules of induction; but had we lived in that

* Tableau des genres, etc. Dictionnaire Universelle d'Histoire Nat., Art. Végétaux Fossiles.

æra, and had been called upon to decipher the monuments of a glacial period of high relative antiquity,—had the phænomena of the drift constituted the first or oldest chapter then extant of the earth's autobiography, instead of happening to be, as it now is, the last and newest, we should have been in danger of indulging for ever in the most visionary and extravagant hypotheses. Ignorant of glaciers and icebergs, and perhaps of ice and snow,—unable to comprehend the nature of that mysterious power which had polished the surface of rocks over wide areas, or had engraved upon them long rectilinear and parallel furrows, we should have gazed upon these markings, and upon the confused and unstratified heaps of clay and loam, interspersed with boulders, and usually devoid of fossils, in stupid amazement and with feelings of despair. The enormous bulk of some erratics, which had travelled for hundreds of miles from their original sites, would have confounded us, and might well have tempted a geologist to dream of frightful catastrophes, and diluvial waves of prodigious velocity, which swept over the planet in its infancy, before it was fitted for the reception of the higher animals and plants, much less to become the home of man. If any one then doubted that there had been an æra of paroxysmal violence, or of primæval chaos, and wished to refer all geological appearances exclusively to the agency of slow and ordinary causes, he would have been asked to explain the position of fragments of granite, like those of Scandinavian origin, on the plains of Pomerania, or of protogene from Mont Blanc lodged on the summit of the Jura, and such an appeal in refutation of a theory apparently so visionary must have been triumphant.

But it is now time to conclude; and in taking leave of you, Gentlemen, I will venture to indulge the hope, that on some future occasion I may resume this theoretical discussion, which ought to embrace every department of geological inquiry, including that of palæontology, to which as yet I have been able to make but a few passing allusions.

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TRANSLATIONS AND NOTICES

OF

GEOLOGICAL MEMOIRS.

On the Tertiary Formations of SPAIN ; *extracted from the* "Anales de Minas," *published by the Direccion general del Ramo.* Madrid, 1838–1846.

OUR knowledge of the geological structure of Spain is so slight, that I have been induced to extract from the above-mentioned work such portions as bear upon this subject connected with the tertiary formations of that country.

The first paper to be noticed is one by D. Joaquin Ezquerra del Bajo, on a portion of the South of Spain, in which he states that it is useless to attempt making a geological map, inasmuch as even a good geographical map of the Peninsula does not exist.

Respecting the geological structure of the South of Spain, only two small works had been published before 1838 ; the one by Colonel Silvertop in 1836, entitled, "Geological Sketch of the Tertiary Formations of the provinces of Granada and Murcia ;" the other by M. Le Play, a French engineer, who has published in the 'Annales des Mines' two memoirs, in which he gives the results of observations made on a journey of three months in 1833.

Tertiary formations of Andalusia.

The form and configuration of the Mediterranean basin was very different during the tertiary period from that which exists at present ; the mountains of Granada and Ronda then rose up as islands out of that tertiary sea. At a subsequent period the marine tertiary deposits of Andalusia were disturbed by the eruption of volcanic rocks, the effects of which were most sensible to the south of the Sierra de Grenada, being hardly felt on the side of the Guadalquivir. The rocks which occasioned these disturbances were doubtless the trachytes so abundant between Malaga and Cape de Gatte, near which latter place basaltic eruptions have taken place on a large scale.

Besides these tertiary marine deposits, there exist also freshwater deposits, which not only overlie the others, but preserve their horizontal position, not having been disturbed by subsequent eruptions. This is also the case with the vast freshwater tertiary deposits in the centre of Spain, and is a proof that they belong to a more modern period. The fossil shells found in them belong moreover to existing species.

The author gives the following list of Mollusca found in the tertiary marine formations of Andalusia :—

Strombus gallus.
Ranella gigantea.
Pleurotoma colon.
Turritella subangulata.
——— colon.
Calyptræa trochiformis.
Natica lyrena.
Dentalium Boueii.
—— hexagonalis.
—— striatus.
Corbula revoluta.
Cardita squamosa.
Lucina incrassata.
Pecten nodosus.
—— burdigalensis.
Ostrea callifera.
Balanus tintinnabulum.
Pollicipes ?
Caryophylla indeterminata.
Clypeaster altus.
—— Kleinii.

and adds that this list might be greatly augmented, if there were only one person in Andalusia who took an interest in this branch of Natural History.

The second volume contains a paper on the tertiary formations in the neighbourhood of Burgos, by Don Felipe Naranjo y Garza ; from which I have extracted the following remarks :—

The country to the north of Burgos between the rivers Arlanzon and Ubierna, consists of the following strata in ascending order :—

1. Horizontal beds of reddish plastic clay alternating with fine and disintegrating arenaceous beds of a brown-grey colour, from four to six inches thick each.

2. Beds of gypsum half a foot thick, alternating with grey marls eight to ten inches thick each : and

3. Calcareous beds of greater or less thickness equally horizontal, occupying the upper part of the deposit and crowning the summits of the neighbouring hills.

The varying extent to which these formations have been worn down and denuded has given to the country generally an undulating character intersected by ridges of greater elevation.

The first or lowest of these formations does not contain any organic remains. It is seen near the fountain of Buenavista, not far from the town of Burgos. The second may be observed in the neighbourhood of Villatoro, where compact gypsum or alabaster is abundant, accompanied by selenite and sometimes fibrous gypsum. The third is essentially calcareous, and is seen on the summits of the hills in the neighbourhood of the Monasterio de Gerónimos de Fres del Val. It contains many remains of

Planorbis carinatus.
Limnæus stagnalis.
Limnæus longiscatus.

The author considers the above evidence sufficient to prove that these beds belong to the plastic clay gypseous marls, and siliceous freshwater limestone, and consequently to the most recent tertiary formation. The fossil remains prove that the basin was at a recent geological period covered by a freshwater lake, in which the above-mentioned beds were tranquilly deposited.

The lowest of the three groups was only visible in a few localities ; the author had consequently no opportunity of ascertaining whether it contained the remains of mammiferous animals. Proceeding to the

N. and N.E. the marls and gypseous beds are constantly capped by beds of lacustrine limestone which continues as far as the Sierra de Peña Orada, where it rests against the chalk and greensand formation.

This tertiary basin, which may be called that of the Ebro, in addition to what has been already said, is remarkable for its extent, its abundant supply of water, the fertility of its soil, and its great elevation above the level of the sea. The author has accompanied his remarks with a map of the district round Burgos, on which he has roughly laid down the principal geological features.

The same volume contains an account of the geology of Estremadura, and the northern parts of Andalusia, translated from the French of M. Frederic Le Play. The following is an abstract of the remarks relating to the tertiary formations. They occur on the northern flank of the Sierra Morena, in the immediate vicinity of Cordova. The most characteristic rock is an earthy shelly limestone, rather incoherent and porous, containing many organic remains, chiefly Terebratulæ and others resembling those found in the island of Corcega, noticed by M. Deshayes.

These shelly limestones rest on a more ancient formation, consisting of fine argillaceous marls of a grey colour, disintegrating easily, and crumbling away under the influence of atmospheric action. Near the town of Cordova it forms an escarpment 80 varas* thick, along the face of which the beds generally appear to be horizontal, although really inclining slightly to the S.S.W., dipping under the transported matter of the third tertiary period which constitutes the greater part of the lower plains of Andalusia. These marls resemble in outward appearance the grey marls which accompany the gypsum of the Paris basin. No organic remains have yet been found in them, although it is probable that they exist, and that they belong to the same period as those found in the shelly limestone which rises almost to the same level on the opposite banks of the Guadalquivir.

In the tertiary basin situated on the table-land which forms the plain of Espiel, is also a limestone containing freshwater shells, which, like those of the same character in other places, appear to belong to the intermediate or miocene period of the tertiary formation.

In the neighbourhood of Badajoz the Guadiana has cut its way through a range of hills, in the escarpment of which is a series of beds of grey marly limestone, penetrated by small cylindrical cavities. Freshwater fossils, resembling those of the lacustrine limestone of the second tertiary deposit, have been found in one or two places in the escarpment. Further to the east these rocks pass, without any line of demarcation, into one of a totally different character, probably siliceous from its not effervescing with acids. After describing the dolomitic rock in the neighbourhood of Badajoz, and the euphotide or igneous rocks by which the crystalline dolomite has been penetrated, the author comes to the conclusion that the dolomitic rocks are derived from the metamorphism of the freshwater limestone by the agency of the injected euphotide.

The tertiary formations of the third period are described as con-

* The vara of Castille = 2·778 English feet.

sisting of old transported materials. They play an important part in the centre of the Peninsula, since the great table-lands of Castille and La Mancha and the plains of Andalusia consist almost exclusively of this modern formation. We find throughout the whole of Castille deposits apparently formed by the heaping together of violently transported materials, and which in this respect differ entirely from the marls, gypsum and compact limestones on which they lie. This formation consists principally of rolled quartz pebbles accumulated in great masses, either without any coherence, or cemented together by a ferruginous argillaceous matrix. Numerous observations tend to show that this boulder formation belongs to the third tertiary period. In Old Castille it overlies the freshwater limestone of the middle period, and on the borders of the Mediterranean, from Malaga to Gibraltar, it overlies shells characteristic of the third tertiary epoch.

In the neighbourhood of Cordova this diluvial formation overlies the second tertiary deposit; and on the E.N.E. side of the city is an argillaceous deposit full of rounded stones overlying the shelly limestone, which contains Terebratulæ and other shells identical with those of the formation of Corcega. The transported matter in the basin of Badajoz consists of a conglomerate of rolled stones, with an argillaceous cement, collected in banks 60 or 70 varas above the Guadiana. The rocks of which the conglomerate is made up are principally quartzites, grauwacke slates, and other transition rocks, which are also found *in situ*.

The same volume (p. 213) contains an account of a tertiary formation in the immediate neighbourhood of Madrid, by Don Joaquin Ezquerra. It consists of a freshwater gypsum, having at a considerable distance from each other two bone-beds, containing mammalian remains. In the lower of these beds were found the remains of elephants and mastodons, exhibited in the National Museum of Madrid. The upper bone-bed consists of a fine siliceous sand, of a bluish-white colour, and about a foot in thickness. The mammalian remains are very numerous, but are almost all waterworn and injured by transport, and difficult to be identified. The author, mistrusting his own palæontological knowledge, submitted them to the examination of Prof. Bronn of Heidelberg. They have been referred to the following species: *Mastodon longirostris*, Kaup, *Mastodon Aurelianense*, Cuv., *Sus palæochærus*, Kaup, and a ruminant resembling the deer, and called *Cervus matritensis*.

Prof. Bronn, in a letter to the author, has given it as his opinion, derived from an examination of the organic remains, that they belong to the miocene period, inasmuch as all the above-mentioned species are most abundant in the formations of that period, and he consequently considers this bed as belonging to the same age as the basins of Vienna and Mayence.

The third volume contains a geognostic and mineralogical description of the district of Catalonia and Aragon, by D. Amalio Maestre, from which I have extracted the following observations on the tertiary formations of that region. The tertiary formation of the plain of Tarragona is about 150 varas in thickness, varying somewhat occa-

sionally according to the undulating nature of the hills on which they were deposited.

The following is the order of the beds in ascending series, the lowermost lying irregularly on granitic, porphyritic and cretaceous rocks.

1. A bed of blue and yellow clay, 2 or 3 varas thick, without fossils, but occasionally containing thin beds of impure lignite.

2. A bed of yellow calcaire grossier, sometimes marly, containing whole and broken fossils, amongst which are the genera *Venericardium, Ostrea, Conus, Pecten, Mytilus, Trochus, Turritella, Balanus, Clypeaster,* besides claws of crabs, fragments of madrepores and other zoophytes. Its thickness is not more than 10 or 12 varas near Tarragona, but it sometimes exceeds 70 at no great distance, where the characteristic fossils are *Conus deperditus* of Lam., and *C. Noe* of Brocchi. It is used as a building-stone, although easily destructible.

3. A white siliceous formation of white sand, without fossils, 2 or 3 varas in thickness.

4. Another sandy bed, resembling the former, with the same specific characters, differing only in colour, inasmuch as this is yellow and somewhat harder.

5. A bed of oysters connected by an argillaceous matrix. Amongst these, *O. giganteus* is most remarkable.

6. A white hard siliceous limestone with conchoidal fracture, earthy, and from 15 to 20 varas in thickness, the principal feature of which is its containing many sharks' teeth, as well as the palatal bones of the same fish.

7. Another sandstone, the calcareous grains of which increase in size until it becomes a conglomerate. Its thickness is from 6 to 10 varas. It occurs in the upper part of the city of Tarragona, and was used in the construction of the ancient Cyclopean walls.

8, and lastly. A transported diluvium, more or less considerable and cemented together, but which, from its connexion with the other rocks, may fairly be considered as belonging to the same period.

The remaining thickness necessary to make up the above-mentioned 150 varas consists of beds of gypsum occasionally interposed between the second and third beds.

It is not unusual to find some of these beds wanting, the thickness of the others being increased. Along the coast the fossiliferous calcaire grossier generally lies upon the chalk, and is covered over by the conglomerates.

The best section of the tertiary formation of Tarragona is from the Puerta del Milagro, or Fuerte della Reina, on the east of the city towards the landmarks on the heights half a league distant between the Fuerte del Olivo and the ruined palace of Lorito.

An extensive tertiary formation occurs proceeding south from the Seu de Urgel, stretching by the mountain of Montsec, and then turning west into the Conca de Tremp, and east towards the flanks of Montserrat. Extending to the south it covers a large portion of the province of Tarragona, a considerable part of which was formerly occupied by a large freshwater lake, according to the fossils found therein (*Paludina, Limnæus, Planorbis, Nerita* [*Neritina*?], *Helix,*

&c.). Towards the north it occupies a large portion of the province of Huesca.

The whole of the tertiary formation which occurs in the province of Barcelona corresponds with the lower formation hereafter described, containing, between Miralles, Copons, Segur, and Calaf, several beds of good lignite, as much as ten feet in thickness. That of the provinces of Lerida and Tarragona corresponds with the upper portion, characterized by a great developement of gypseous rocks, the thickness of which exceeds eighty varas.

The general section of the tertiary formation, in ascending order, and with a variable thickness, gives us an incoherent conglomerate of rolled pebbles chiefly calcareous; beds of reddish plastic clay; marls more or less siliceous, yellowish, and graduating into sandstones; sandstones of the same colour, and generally fine-grained; gypsum, chiefly laminated and but slightly compact, of a white or light reddish colour; grey and yellow clays; and finally, deposits of rolled pebbles of older rocks more or less cemented together. Some of these beds are wanting in certain localities.

The principal features in these deposits are the above-mentioned lignites, the sulphates of soda in the neighbourhood of Cervera and of Artesa de Segre, and the quicksilver of the city of Lerida.

The gypsum which occupies the greater part of the confines of Robinat, one league distant from Cervera, is strongly impregnated with sulphate of soda; and a considerable quantity of this salt is obtained by evaporation of water saturated with it by means of artificial excavations in the gypsum into which the water is conveyed.

Near the junction of the Segre with the Ebro, dark bituminous and fœtid limestones are first seen. These are underlaid by beds of excellent free-burning lignite, varying in thickness from two inches to two feet. This fuel was used at very distant periods. Of late its use has considerably increased. The best lignite of the Segre and the Ebro has a specific gravity of 1·26. It burns easily, leaves ten per cent. of ashes, and makes a good coke. The principal difference between this and the various lignites of Aragon and Catalonia consists in the great quantity of vegetable impressions it contains, as well as fossils of the genus *Planorbis*, which are sometimes two inches in diameter, and form white stains in the middle of the coal. The limestone on which it rests also contains many fossils, but they are entirely confined to the genera *Planorbis*, *Limnæus*, and *Paludina*. The general thickness of the lower deposit of the tertiary formation of Lerida is not less than 200 varas, and terminates under the beds of lignite, with others of marl, sandstones, conglomerates, and clays, resting on the rocks of the cretaceous group.

A considerable portion of the province of Zaragoza is covered with recent freshwater deposits; of these however no detailed account is given.

The province of Teruel consists for the greater part of tertiary beds, forming a lacustrine formation covering 25 square leagues*. The author has divided this formation into four groups for the

* The Spanish league = 4 miles, the square league therefore contains 16 square miles.

sake of greater convenience, although not representing distinct periods.

I. The first group contains the hills in which the village of Concud is situated, north-west from Teruel. It consists of beds of gypsum white or reddish, crystalline or compact, without any fossil remains; of a bed of dark vegetable soil resembling dried mud containing numerous bones of mammifers, viz. the ox, hyæna, horse, &c., with their teeth, the bones and molar teeth of mastodons, and the incisor teeth of a large ruminant. The bones are well-preserved, the medullary canal is sometimes filled with calcareous spar. The teeth are in still better preservation, but the large ones fall to pieces on coming in contact with the air. Below this bed is another 40 or 50 varas in thickness, of reddish or brown gypsum, showing in many places an efflorescence of sulphate of soda, and containing a new mineral which the author calls Teruelite, supposing it to be a carbonate of lime and iron. Prof. Breithaupt afterwards considered it as a variety of Bitterspar analogous to what he had found in the gypsum of the salt-mines of Tyrol called Braunerite. Its chief locality is the neighbourhood of Teruel. Below this gypsum are beds of calcaire grossier containing many freshwater fossils in excellent preservation, particularly the Limnæi and Planorbes, which, on being extracted, look as if they had been only recently deposited. These beds rest on calcareous sands and conglomerates without fossils.

II. The second group consists of almost horizontal beds of a yellow siliceous limestone full of the same freshwater fossils completely petrified; conglomerates and yellow sands in thick beds with few fossils again succeeded by siliceous limestones. This group may be traced for about six hours down the banks of the river Guadalaviar, which flows out of the above-mentioned lacustrine plain.

III. The third group is best seen between the heights of Morron de la Nava and Ademuz. The following is the series of beds in descending order:—

1. A yellow hard siliceous limestone with conchoidal fracture containing Planorbis and Paludina.
2. Compact reddish-brown gypsum.
3. Siliceous limestone with Planorbis and Paludina, giving out a fœtid odour when rubbed, in consequence of its containing sulphur.
4. Black limestone, hard and fœtid from the same cause.
5. Compact gypsum, white or reddish-brown.
6. Calcaire grossier, white and earthy, with the same fossils.
7. Gypseous marl, bituminous and dark-coloured, with crystals of gypsum and carbonized vegetable remains.
8. Specular and fibrous gypsum.
9. Sulphur.
10. Grey bituminous gypseous marl.
11. Calcaire grossier with fossils.

The first six beds form a thickness of about 80 varas; the seventh, called in the country *piedra de encovar**, has a thickness of 1 or $1\frac{1}{2}$ vara, and serves as a sure guide to the miners in searching for the

* *Encovar*, to put anything into a cellar, to lay up in a cellar.

sulphur with which it is invariably associated. The sulphur occurs either in pure yellow nodules containing more than 95 per cent., or in masses of a brownish or greenish grey containing from 50 to 60 per cent. of sulphur, with numerous Paludinæ, Limnæi and Planorbes converted into sulphur, as well as coniferous and aquatic plants, the form of which is perfectly preserved.

Seven beds of this combustible have been hitherto discovered regularly alternating with the bituminous gypseous marls. The most abundant is found in the mine called Santa Ana de Herrero, which has a thickness of 6 palms; they increase in produce to the north as far as a spot called Zarcillos y Humbria de Cascante. They all incline 6° to the east.

IV. The fourth group, the lowest of the tertiary formation of Teruel, consists of sandstones and coarse limestones (calcaire grossier) without fossils, blue marls with beds of lignite a foot thick, but of inferior quality, and lastly of sandstones graduating into conglomerates resting on the cretaceous formation.

Finally, it is stated that considerable beds of lignite, used for various purposes, are found in the province of Teruel, in the neighbourhood of Utrillas, Montalban, Peña-roya, Alloza, Rubielos de Mora, &c., the strata of which belong to the lower portion of the tertiary formation. These lignites may be considered as the continuation of those of Mequinenza and La Granja de Escarp in the provinces of Lerida and Zaragoza, which, according to the geological conditions of the country, are a counterpart of the province of Castellon de la Plana.

The same volume (p. 300) contains a memoir by Don Joaquin Ezquerra del Bajo on the tertiary formations of Central Spain. After lamenting in pathetic terms the want of zeal for the study of natural history amongst his countrymen, and giving a general outline of the great geological phænomena, the author proceeds to describe the tertiary basins of the Douro, the Tagus, the Ebro, and the Guadiana.

Basin of the Douro.

The tertiary formation of the basin of the Douro extends from south to north, from Mingorria in the province of Avila, to beyond Saldaña in the province of Palencia, a distance of 40 leagues. On the west it extends to Salamanca, Zamora, and Benavente, and on the east to near Reynosa. The Douro flowing from east to west, this district is bounded on the north by the Asturian Pyrenees, and on the south by the northern slope of the mountain-chain of Guadarrama. Its whole extent may be calculated at 1600 square leagues, perhaps the most extensive tertiary lake or lacustrine formation which has existed.

The different beds of this formation, with their various relations, are best seen in the centre of the basin, at a distance of 8 or 10 leagues on each side of the Douro; here the formation is laid bare to the thickness of 500 feet in the ravines and water-courses opened out by the rivers. The beds are all horizontal, from whence it may be inferred that no eruptive agencies have been at work in this district since its deposition.

The different strata which have hitherto been examined have been

classified by the author in three distinct groups or series. The upper series is mainly calcareous, the intermediate gypseous marly, and the lowest principally argillaceous.

The upper series is 50–60 feet thick in the centre of the basin; none of the separate beds are above four feet thick; they are chiefly calcareous, but alternate with others of sand, marl and clay. The lime contains a little silex, and nodules of ferruginous sandstone. In some places it contains numerous remains of *Limnæus socialis*, *Planorbis carinata* and *Paludina impura*, all of which are still existing freshwater species. In other places, as near Arévalo, the limestone is more siliceous, and in proportion as the lime disappears, the result is the production of a kind of semiopal and chalcedony, as in the neighbourhood of Vicálvaro and Vallecas, in the basin of the Tagus. All these characters agree with what geologists call "the siliceous freshwater limestone."

The middle group has a thickness of more than 200 feet. The beds are generally marly, alternating with argillaceous beds, and all filled with an extraordinary abundance of beautiful crystals of selenite. In the lower portion of the gypseous series is often found a limestone bed three feet thick abounding with Limnæus and Planorbis. This limestone is not honeycombed like the former and contains but little silex; consequently it is not so hard or compact, and cannot be used like the other for mill-stones.

The thickness of the beds of the lower series has not yet been ascertained. It begins with a thick bed of *Nagelfluhe*, in some places sixteen feet thick. This is nothing but an agglomeration of rounded pebbles of various sizes joined together by a cement at times sufficiently hard to be worked into hewn blocks. Below it is an argillaceous bed, varying not only in thickness but in character; at times it is pure white and compact, as in the vicinity of Palencia, where it is used as a kind of fuller's earth for washing stuffs; at others it is bluish, mixed with marl, and contains an immense quantity of the fossils above mentioned. Below these beds of clay are others of sand, marl and clay alternating irregularly; sometimes the nagelfluhe again occurs of very moderate thickness, the pebbles being very loose and forming a true gravel. All this would appear to show that when these lower beds were deposited, there existed great currents of water flowing in different directions. This is also proved by the isolated remains of large pachyderms which are there found. The skeleton of an individual of this kind was found a few years back near Sopeña, six miles north of Valladolid, in the excavations made to open the canal of Castille. Sufficient attention was not paid to these relics, but from the examination of a tooth which was preserved, the author is disposed to attribute them to the genus *Mastodon*. Near Paredes other bones were found on a similar occasion, of which the author obtained a femur and a molar tooth belonging to *Mastodon angustidens* of Cuvier. It would therefore appear that the whole of the sedimentary deposit which has filled up the basin of the Douro belongs to what geologists have called the "gypseous tertiary freshwater."

Basin of the Ebro.

The Ebro also during a portion of its course traverses a tertiary formation exactly resembling that of the basin of the Douro. The siliceous freshwater limestone, the gypseous beds, and those of the nagelfluhe, the clay and loose sand, alternate in the same order and manner; the remains of mollusks which they contain are the same, viz. *Lymnæus socialis* and *Planorbis carinata*. Nevertheless the tertiary formation of the Ebro has some peculiar features which distinguish it from that of the Douro: in the first place, all the rocks which constitute the tertiary formation of the Ebro have generally a reddish-brown tinge caused by an oxide of iron; the gypsums also have the same colour. 2. The form of the crystals of selenite is different. 3. In the gypseous series, and in the lower portion, it contains great saline deposits, which are not found in the basin of the Douro. 4. No remains of large mammifers have yet been found; for although a vast deposit of the remains of *Equus primigenius* and of *Bos* have been found at Concud in Aragon, forming breccias which fill certain crevices in the tertiary soil, they must belong to a more modern period.

The author is unable to give the limits of this basin; he merely observes that the beds, which are clearly horizontal, rest on the north, against the flanks of the Pyrenees. To the south it extends to Alama, and on the west to the sloping sides of Moncayo. The great desert of Navarre, called Las Bardénas, forms part of the tertiary district. Here there must also have existed during that period a great freshwater lake, probably several of smaller extent, connected with each other, as is now the case in the Alps.

Basin of the Tagus.

The tertiary formation of the basin of the Tagus is entirely analogous to the two above mentioned, but more closely resembles that of the Douro. The siliceous freshwater limestone, which as we have observed occupies the upper portion, may be seen in the plain of Torija, in the neighbourhood of Guadalajara and Alcalá, in Vacia-Madrid, Colmenar de Oreja, Tembleque, and various other places. It must be remarked, however, that the remains of mollusks hitherto found in it are more varied, inasmuch as besides those already mentioned, it also contains *Helices*, and perhaps some other genera. The range of hills of Vallecas and the soil of Vicalbaro undoubtedly belong to this upper series of freshwater limestone, as we have already observed respecting the neighbourhood of Arévalo in the basin of the Douro, which it exactly resembles.

The currents of the Tagus and of its affluents have in many places laid bare the gypseous group, as may be seen immediately outside the gate of Atocha; but the clays and marls of this series have a dark blackish colour, as is sometimes also the case with the gypsum, which crystallizes in a distinct manner from that of the Douro or the Ebro.

In the basin of the Tagus are also many large rock-salt deposits. The lower group of the nagelfluhe, in which the remains of the great mammifers have been found, has not yet been entirely worked out; it has been however partially examined, and from it were taken the remains of elephants and mastodons preserved in the rooms of the Museum of Natural History.

The limits of this great tertiary basin have not yet been made out, although some few points may be given. To the north-west it rests against the primitive rocks of the chain of the Guadarrama. To the south it reaches a little beyond Mora and Tembleque, extending by Villatobas and Villamanrique to the slopes of the mountains of Alcarria.

"In conclusion, it may be said that the gypseous tertiary formations of these three basins are characterized in the following manner:—

1. By the form and colour of the crystals of gypsum, which are different in each of them.

2. In the basins of the Ebro and of the Tagus there are salt deposits, but none in that of the Douro.

3. In none of the three basins have any fossil vegetable remains been met with, as far as I am myself aware.

4. In all these basins freshwater mollusks are found, but in that of the Tagus the genera are more varied.

5. In the basins of the Douro and of the Tagus detached isolated remains of great pachyderms have been found: these, as yet, have not been found in the basin of the Ebro."

Basin of the Guadiana.

There is not much to say respecting the tertiary formation which is traversed by the Guadiana. It is only mentioned for one remarkable peculiarity it possesses, and which distinguishes it from the three above mentioned. In them, as has been said, the streams of water have opened large ravines and have formed great channels, which serve as beds to the actual rivers; this circumstance has exposed the whole formation, thus greatly facilitating the study of the naturalist. This is not the case in the basin of the Guadiana; the surface or upper stratum is there as yet almost untouched; neither rivers nor constant streams flow over it; consequently in the rainy seasons, and during the melting of the snows of the Sierra Morena, the water flows indiscriminately in all directions. In order to guard against the mischief, some village districts have opened great drains to carry it off, thus protecting their fields and their cottages in times of excessive rains. But if there are no superficial streams, internal or subterranean streams are very abundant. The phænomenon of the "ojos de Guadiana" recurs in many instances, although on a smaller scale, and wherever a well is opened, there is a certainty beforehand of meeting with water at a very inconsiderable depth.

The cause of this phænomenon appears to the author to be partly attributable to the existence of certain subterranean strata of calcareous tuff in some districts forming hollows and cavities, which are

so many deposits of water, which, in seeking to escape, flows underground through the most porous beds of the formation.

These calcareous tuffs may be seen on both flanks of the mountains of Alcaraz, both on the side of Riopar and at Villanueva de la Fuente, with this peculiarity, that in the tuff we find numerous remains of the same shells which characterize the other tertiary basins, mixed moreover with the remains of plants which do not now grow naturally in those districts, but which are characteristic of the tertiary period.

With regard to the boundaries of this tertiary basin, the author can only state that towards the north it is determined by the southern slope of the mountains of Toledo and its ramifications, and to the south by the northern flank of the Sierra Morena. In other respects this lake cannot have been of such extent as those above mentioned; and when we take into consideration the country in the neighbourhood of Valdepeñas towards Santa Cruz, we may be assured that it must undoubtedly have contained several islands of greater or less magnitude.

This interesting paper is followed by another by the same author, describing in detail the different barriers of these tertiary basins, by the gradual or sudden breaking up or wearing away of some of which the different districts have been drained.

In the fourth volume there is a memoir by the same author, giving a description of the mines of Farena and of the geology of the neighbourhood of Tarragona. In the excavations which have lately taken place near this town an extraordinary quantity of fossils has been found, almost entirely belonging to the species *Conus antediluvianus* of Brocchi and *C. deperditus* of Lamarck, from whence the author concludes that the beds belong to the eocene or lowest group of the tertiary or supracretaceous period. This marine tertiary formation extends along almost the whole coast of Spain, as well as that of Italy and of the north of Africa. But it is not only along the coast that it is met with; in some places it extends far into the interior. Near Tarragona it runs up beyond Reus, forming the basis of the rich plain of Tarragona, contributing by the different elements of its composition to the fertility for which that region is so highly celebrated.

In the same volume (p. 191) is another memoir, by Don José Aldama, giving geological and mining remarks on the province of Huesca, and part of that of Zaragoza, or the territory designated as Upper Aragon. As in the former part of these extracts, I confine myself to that portion which describes the tertiary deposits of this district. The details are not so full as could be desired, but they are all the author was able to collect.

Many spots on the left bank of the Ebro are occupied by tertiary freshwater formations; but the component parts and strata are not the same in all places, owing to the different causes from which they have resulted. One of the so-called tertiary basins or formations extends through the region of Tamarite in the province of Huesca, and is composed of marls, limestones, sandstones, conglomerates, and gypsums of all kinds and colours. On the banks of the Cinca, in the

district of Estadilla, traces of brown coal or lignite appear on the surface, between marls of dark colour and bituminous limestones, as well as clays of various dark colours, containing crystals of selenite, plates of mica, pyrites, sulphur, and assuming in some places the appearance of burnt plastic clay. This, as well as a bed of lignite, which, with slight interruptions, extends through the whole ravine of Nuestra S^ra^ de la Carrodilla, has led to the supposition of the existence of beds of coal at a great depth, and has given rise to the belief that this formation is the continuation of those which extend from the south-west of Lerida to the Ebro and the Segre. It burns well, with a bright flame, gives out much smoke, and emits a fœtid ammoniacal smell.

The neighbourhood of Zaragoza shows that this city is built on a tertiary formation, and evidences of old lacustrine deposits, with their peculiar fossils, occur in the surrounding districts. The basin of the Gallego also consists principally of freshwater limestone, gypsum, marly gypsum, sand, sandstone and argillaceous marls. The freshwater limestone is compact grey or whitish-yellow, containing lacustrine shells, principally *Limnæus* and *Planorbis*; it is abundant in many places as well as the gypsum, which is much worked, and is both granular and laminar. The gypsum is found alternating with calcareous and argillaceous marls. Other beds of sands and marls are described in different positions belonging to this formation, and particularly a bed of agglomerated sandstone six miles south-west of Huesca, consisting of fine-grained sand of a reddish-brown colour, sufficiently cemented together to be used for building purposes.

The above extracts from these Spanish 'Anales de Minas,' show that some progress is being made in that country in geological investigations, and that an interest for the science has already taken root there, which we trust will flourish and in time produce good fruit.

W. I. H.

On the Fossil Flora *of the* Coal-formation, *especially in* Silesia. By Professor Göppert of Breslau.

In the year 1844 the Haarlem Scientific Society offered a prize for the following subject: "To determine by a careful examination of the various seams of coal, whether the beds of coal were formed entirely out of plants that grew on the spot, or whether they originated from vegetable matter floated from other places, and also to inquire whether different coal-beds have had a distinct origin."

At the meeting of the Society on the 23rd May 1846, the prize was awarded to an essay by Dr. Göppert. This essay has now been published in a quarto volume, with twenty-two plates of the plants found in the shales and sandstones of this formation, and by Dr. Göppert also in the coal itself. The author gives the following summary of the chief results of this essay* :—

* Karsten und v. Dechen's Archiv für Miner. (1849).

I. Fossil carbon, and its uses, were well known in ancient classical times, though perhaps not the stone-coal as commonly understood. This appears to have been employed in China earlier than in Europe, where its use does not go back beyond the year 1000. The first works were opened about the year 1198 in Belgium, soon afterwards in England and Scotland, in the fifteenth century in France and Germany; probably first at Zwickau in Saxony, from which the use of it gradually extended to the other deposits in that country. The discovery of the coal-beds of other countries does not date further back than towards the close of the preceding century, and some even only from our own time. Almost every quarter of the globe, and every zone, including the polar and the southern temperate and tropical zones, are furnished with this mineral, Africa being the sole exception, unless perhaps it has been discovered in Algiers, regarding which I have no certain information. Coal-beds are wrought 1725 feet below the sea level, and probably extend down to 20,656 feet; whilst on the other hand they rise to 12,000 feet above it, and at Huanuco, in Peru, even attain an elevation of 14,700 feet. Almost everywhere this formation exhibits a more or less basin-shaped form of stratification; and so far as is known, also a similar composition of alternating beds of coal, sandstone, and slate-clay, the first being the thinnest, amounting to from 2 to 60 or occasionally as much as 120 feet in thickness.

II. So far as I have ascertained, no inquiries into the origin of the coal-deposits were undertaken previous to the revival of the study of nature in the sixteenth century. Yet even then, in the time of Agricola, who may be considered the founder of our present mineralogy, no one for a moment entertained any doubts of its organic origin. The chief error was in attaching too much importance to the earthy parts occurring along with the coal, which was then regarded as an earth saturated with bituminous matter, an opinion which maintained its ground almost universally even down to the nineteenth century. The more correct view of Scheuzer, that the whole substance of the former vegetation was mixed with the coal, though published at the commencement of the eighteenth century, was for long unheeded; but deserves the more to be rescued from oblivion, since even in our own time the most varied inquiries have on the whole led to no different result. Besides, the history of the gradual development of an idea, even in the field of a special science, is always interesting, and forms a small contribution to our knowledge of the progress of the human mind, and I have, therefore, not thought it improper to treat of it at considerable length. Who knows in how short time all our present knowledge on this subject may possess nothing more than a mere historical importance?

III. Should we now, following the example of Boué, Adolphe Brongniart, Alexander v. Humboldt, Lyell, Murchison and other distinguished geologists, feel justified in assuming that after the deposition of all the so-called transition rocks (the Cambrian, Silurian, and Devonian formations), Europe, or indeed the greater part of the earth, formed an immense sea, with a considerable number of separate

islands, on which a tropical vegetation everywhere prevailed, then I conceive the origin of the coal-deposits may be explained in the following manner. These islands, like similar spots in our time, had their mountains, valleys, rivers, lakes,—their moist and dry, cooler and warmer, shady and sunny localities. A tropical climate extended over the whole, as we may justly conclude from the vegetation, everywhere uniform in character, and only to be compared with that now growing within the tropics: for the fossil plants in both hemispheres,—in southern and northern Asia, at Ekatharinenburg on the Asiatic border, in the Altai and in Siberia, over the whole continent of northern Europe from beyond the Ural, in England, Scotland and Ireland, as well as beyond the ocean, in North and South America, and in New Holland—appear everywhere identical, if not in regard to species, at least in the genera. Stigmaria is almost never wanting, as well as Sigillaria, Sphenopteris, Pecopteris, &c.

Vast forests were formed of the Coniferæ, the tree-like Lycopodiaceæ, seventy to seventy-five feet in height and two or three feet in diameter, the curiously formed Sigillariæ, and the Calamites or gigantic Equisetaceæ, under whose shade numberless ferns, often too arborescent, sprung up, and the singular *Stigmaria ficoides* unfolded itself,—with its dome-shaped trunk expanding in forked branches often thirty feet long and furnished with dichotomising thorny leaves projecting at right angles,—well-adapted to appropriate to itself or cover up the remains of other vegetables. According to the laws of vegetation then prevailing, which were not different from those of existing nature, and in consequence of the relations of climate, this insular flora covered with its luxuriant growth, here the high arid plateaus, there recesses in the hills, in other places the basins and valleys among the still loftier ancient mountains. When this rich vegetation decayed, it was immediately followed by a new growth, as now happens in the tropics; in moist localities also peat-like beds were formed, and thus in the valleys and on the plains, at the foot and on the summits of the mountains, on the plateaus and in the hollows, immense masses of vegetable matter, the material of future coal-beds, were more or less speedily accumulated, according as the soil, the situation and the nature of the different plants favoured a more or less luxuriant growth.

If we now reflect that no mammalia, no birds, in short no animal except a few air-breathing insects, enlivened these dull monotonous woods, then we may form a picture not very wide of the truth, of this melancholy scene—a scene, however, imposing from the part which it has filled in the history of the globe (Brongniart). For its collected vegetation was buried in the strata which form the great coal-formation, having been overwhelmed by the floods produced by the changes in level resulting from elevations and depressions. Where pebbles and detritus were wanting, the plants were converted into continuous seams of coal, but when mixed with sand or clay they were inclosed and preserved in the gradually consolidating shales and sandstones. For my investigations, extended over large beds of coal, have for the first time

decisively proved, what previously was only conjectured, that the coal itself contains plants similar to those found in the shales and sandstones above and below. The plants entombed in the latter could not combine to form beds of coal, because where much sand and clay were brought down with the water, too much earthy matter was in consequence mixed with the vegetable remains.

Even in the coal which is apparently without structure, we are able to find evidence of its vegetable origin, by the process which I first pointed out, of examining the ashes left by burning. In these ashes we find the well-preserved skeletons of vegetable cells, and thus obtain arguments triumphantly to refute the opinion of the inorganic origin of coal, which has recently been again maintained.

These inundations, as I first proved by evidence, spared no part of the vegetation, but generally uprooted and overturned all the trees, such as the Calamites, Lycopodiaceæ, Sigillariæ and Stigmariæ, which, notwithstanding their great length and size, did not consist internally of concentric layers of wood formed of tolerably compact vessels. A few only retained their natural upright position. In consequence of the high temperature of the climate, which we may well estimate at 20° to 25° (77° to 88° F.) on the average, these plants soon fell into a kind of decomposition, which continued sufficiently long to destroy entirely the cells and vessels in the interior, but in many places at least did not extend its influence to the bark, and in general did not result in an entire decay or dissolution, but was checked in its progress by the withdrawal of the influence of the atmosphere. At this stage, however, the Coniferæ or Araucariæ, formed of remarkably dense wood, though buried at the same time with the former plants, had not proceeded so far towards decomposition, and hence could not combine with them in an uniform mass. The connection of the wood was indeed already destroyed, so that it floated about in innumerable delicately minute pieces and fragments, which settling down amidst the more uniform mass, formed the, so-called, mineral wood-coal or fibrous-coal of the mineralogists. We find a proof of the correctness of this opinion, in the well-preserved structure, similar to that of the existing Araucariæ, which is always met with in the remarkable variety of coal, separated by mineralogists under the above name from the other kinds, and strongly characterized by its external aspect, its fibrous structure and soiling properties. The longer or shorter continuance of this process of decomposition,—which, judging from experiments we have instituted on the decomposition of large trunks of monocotyledons, might readily, at a temperature of 25° to 30° (88° to 100° F.), be completed in a single summer,—the deeper or shallower layer of water which covered them, and thus allowed of a more or less powerful influence of the atmosphere;—and the calm or disturbed state of the surface of the waters, are all elements, which admit of infinite modifications, and by which the no less innumerable diversities in the external aspect, the state of preservation and the contents of the stone-coal in the various regions of the earth have been produced. Where the prolonged continuance of the period of decomposition, and the free unchecked access of the

atmosphere, destroyed all the structure of the Sigillariæ, Lepidodendra, and Stigmariæ that was externally visible, that of the Coniferæ, or Araucariæ, naturally kept equal pace with it (*Hand in Hand ging*), and hence in such cases we find the latter mixed with the coal only in very minute fragments; but where, as for example in Upper Silesia, the Sigillariæ and Lepidodendra are so beautifully preserved, we also meet with entire stems of Araucariæ a foot long, an observation which, if I am not mistaken, still further explains the mode of origin above-mentioned of this much-discussed fossil.

The waters, apparently much agitated, brought with them large quantities of sand and masses of clay, which formed the slate-bands, and the bituminous shales (*Brandschiefer*) which are so often mixed with the coal, or even entirely destroy it, as in some seams of the so-called waste-coal or culm (*Kohlenschmitze*), which are not worth working.

IV. All the conditions, however,—the unvarying persistence of the beds over spaces of many fathoms or even miles in extent; the continuance for many fathoms in the coal itself of very thin layers, frequently not more than one or two lines thick; the regular interstratification, often over no less wide spaces, of the so-called fibrous-coal; the condition of the vegetation, which, as in some places in Upper Silesia, is still found included in them,—speak decisively for a very quiet and gradual deposition of the plants collected in one bed of coal.

V. The calculations, however, given by Élie de Beaumont and myself, prove indisputably that the plants which can grow on an equal surface are wholly insufficient to produce a bed of coal so thick as frequently occurs; whilst on the other hand the statements just made, show that we can only have recourse to a peaceful deposition, and not to a drifting together of materials from a wide circuit. Hence it is evident, that to explain this phænomenon, we are compelled to assume that many coal-seams (I am far from extending this assumption to all of them, for nothing is more prejudicial to the investigation of obscure relations than so-called generalizations,) are to be regarded as the turf-beds (peat-mosses) of the ancient world, which were formed during long periods of vegetable life, in the same manner as the turf-beds of the present time often, as for instance in Ireland, attain a thickness of forty or fifty feet. The Stigmaria, which most probably was a moisture-loving plant, with its long dichotomizing boughs spreading out for thirty to fifty feet on all sides of the central stock, and covered with spine-like leaves of an undoubtedly soft, herbaceous nature, attached at right angles, seems highly adapted, with the aid of the Calamites (decided marsh plants) which never fail to be associated with it, to form the basis of such a bed of turf,—a view confirmed by the altogether enormous frequency in which they occur in every coal-bed with which I am acquainted.

VI. In the unaltered vegetable fibre the proportion of oxygen and hydrogen greatly preponderates over the carbon; in brown and common coal the proportion is reversed. In the decaying vegetable fibre the carbon continually increases, whilst the hydrogen and oxygen

uniting in compounds with carbonic acid and carburetted hydrogen, escape when the air has access. Covering up the plants prevents the latter process, or rather only checks it; for, as experience teaches, such combinations are developed in both brown and stone-coal pits when they are opened,—in the former particularly as carbonic acid gas, in the latter as carburetted hydrogen combinations,—and thus prove that a change is continually proceeding, which, when it had deprived the coal of all its hydrogen, would convert it at last into anthracite. This separation of elements, which gradually converted the vegetable mass into coal, took place with the cooperation of moisture or in the *humid way*, as the preservation of all the plants found in the coal-formation proves. Such processes, as I have observed, are occurring even at the present day before our eyes in nature, and, as I proved by experiments, can be designedly produced by means of similar conditions; and this indeed has respect not only to the formation of the brown coals, but also of the common black coal.

The condition of the coal strata broken through by eruptive rocks, —their beds of slate-clay and sandstone burned red by this catastrophe, with the coal partially converted into coke, even the gradual increase or decrease of this appearance, with the greater or less proximity to the eruptive mass,—may also furnish us with a proof of the statement above, since it exhibits the effects of the action of heat (*the dry way*) in such a sharp and decisive manner.

VII. The influence of pressure completed the process of which the commencement is described in the previous section.

The beds of coal already in course of formation were buried below the fragments of ancient mountains, broken up during the eruption of the older massive rocks, or by volcanic showers, violent spring-tides with their detrital deposits, streams of mud poured out from volcanos during these convulsions, or river-sand and lacustrine deposits, which also enveloped the similar vegetation that from time to time appeared in particular localities, and is now met with in the slate-clays and sandstones. At the time of these deposits the coal-beds had already acquired a considerable degree of compactness. This is proved by the impressions formed on the slate-clays and sandstones above them by plants found on the surface of the coal-beds. These were first observed in Lower Silesia by my friend Beiner and myself, and I subsequently saw them still more extensively in Upper Silesia in some of the open workings (*Tagbauten*). Although no one would maintain that this deposition took place everywhere with equal tranquillity, yet my observations in many localities on the distribution of fossil plants, their division into groups, or the social and isolated occurrence of certain species, the absence of one kind and its replacement by another species of the same genus on the roof of one and the same bed of coal, and finally, above all, the wonderful preservation of fossil plants, which sometimes, as in particular points in Upper Silesia and Zwickau, appear like newly-dried, slightly-browned leaves, prove undeniably that they have been buried in the beds of clay and sand either in their original place of growth or at least not far from it.

The diverse physical conditions and the distinct vegetation of the

separate superimposed beds, whether of coal or of slate-clay and sandstone, teach us that, although they belong to one formation, as is shown by the generic agreement of the plants contained in them, they have yet been produced at different times, and deposited in long periods during which the conditions above noticed as acting in the formation of the strata were repeated. Though far from wishing to make even an attempt to determine the length of time in which these beds were formed, yet referring to many observations quoted in my work on the quick renewal of the flora in tropical regions, and also on its remarkably rapid decomposition, I would remark that a shorter period is required for this purpose than it has been usually thought necessary to assume.

In respect to the diversity of the coal-beds in Upper and Lower Silesia, Professor Göppert makes the following observations:—

1. The predominant vegetable origin of the coal in Upper as well as Lower Silesia cannot be doubted. In the former marine productions are entirely wanting, and hence the sea probably had no part in their formation. In the Lower Silesian deposits marine fossils occur along with land-plants only in some single limestone beds in the red sandstone above the coal.

2. The large thick stems of Sigillaria, which are found well preserved in the coal itself in almost every locality, contributed the most to the formation of the coal in Upper Silesia. Hence the coal of many extensive tracts, as for instance of the Nicolai district, of the pits on the Przemsa in Silesia, in the kingdom of Poland, and in the free state of Cracow, may in general be well designated as Sigillaria-coal (*si à potiori fit denominatio*); and to this circumstance we may perhaps also ascribe the immense thickness of the coal in this basin, sometimes reaching to seven fathoms.

None of the other large families of carboniferous plants, with the exception of the Araucariæ, occur here in such abundance in the coal. The Lepidodendreæ (Sagenaria) and Stigmariæ only preponderate in individual beds, as in the Friedrich's pit near Zawada, and with them the Calamites. The Calamites and Nöggerathia are found only sparingly; the Ferns are everywhere wanting in the coal, or at least have not yet been found by me after the most diligent search for them; and we may perhaps assume that they were originally wanting at least in those points where the Lepidodendreæ with its so delicate bark is found well preserved, as in the Friedrich's pits mentioned above. In Lower Silesia the beds nowhere attain the thickness of those in the upper province. Although Lepidodendreæ are abundant in the slate-clays, and Sigillariæ also occur, though fewer, and the fibrous variety is never wanting in the coal, yet the former are only observed much dispersed and isolated in the coal itself, whilst *Stigmaria ficoides* appears in incredible abundance, and probably, with a great multitude of herbaceous plants like ferns, whose structure has almost entirely perished, formed the coal-beds, which, however, must be of inferior thickness, since these plants could not furnish such a mass of vege-

table matter as the colossal Sigillariæ. In general the greater part of the Lower Silesian coals may be described as Stigmaria-coal.

Among forty-six pits in Lower Silesia which I visited, only ten furnished more or less distinct remains of Sigillaria, and only in one, the Sophia-pit in the county Glatz, can we reckon with any certainty to find specimens even in a large quantity of coal; whereas in the eighty pits in Upper Silesia, there are only about six in which these plants have not been observed, and how abundant they are in the others has been already mentioned.

3. In Upper Silesia thick seams of coal, extending over many leagues, show similar external peculiarities, and appear also composed of plants of the same genus or species. The coal-seams in the pits on the Przemsa near Myslowitz, whence they extend to the free state of Cracow and to Dombrowa and Jaworzno, are an example of this.

The same thing is seen in Lower Silesia also, though, from the smaller extent of the beds, not over such wide distances.

4. Superimposed seams of coal exhibit distinct physical peculiarities and distinct vegetable contents, as is particularly seen in the different beds of the Friedrich's pit, of that at Dombrowa, of the Queen-Louisa pit, &c. In Lower Silesia the less distinct vegetable structure of the coal compels us to consider chiefly its physical peculiarities, but these lead to similar results. In a few places plants furnish also some information.

5. The slate-clays and sandstones resting on the coal-deposits are not synchronous in age with them, but have been deposited after the formation of the latter. This appears not only from the diversity of the floras they contain, but especially from the relation of the slate-clays to the inferior coals, since the slate-clays and sandstones exhibit impressions of the plants still preserved in the coal, as is seen not only in Lower Silesia in the Carl-Gustav pit near Charlottenbrunn, but in many places in Upper Silesia, on the most magnificent scale, over spaces many fathoms wide, in the open workings common there.

6. A considerable diversity also appears in the flora contained in the different beds of slate-clay in Upper Silesia. The same mode of distribution occurs here as in the coal. The ferns, so remarkably common in other coal-deposits, are, with the exception of a few points, in the Agnes-Amande pit at Königshütte near Zalenze, among the most sparingly distributed plants. This contributes to confer on the fossil flora of Upper Silesia a very monotonous character. I have also proved most distinctly the diversity of the flora contained in the individual beds of slate-clay interstratified among the coal-seams in several points in Lower Silesia. Among the families of plants the ferns almost everywhere predominate, as well in regard to the quantity of the mass, as the multitude of the species; but in most localities associated with plants from all the families known in the coal-formation, so that a great variety is here the chief character of the carboniferous vegetation in contradistinction to the uniformity prevailing in Upper Silesia.

7. Wherever it is possible to make observations of this kind, either in or upon the coal, or in the slate-clays, no doubt is left that

the plants are deposited in groups, assuredly a kind of gregarious occurrence, with the predominance of one or the deficiency of other species, or the wholly isolated appearance of some species. *Stigmaria ficoides, Calamites decoratus,* and certain Sigillarias are almost never wanting in Upper Silesia, and to these we must add in the coal sandstones everywhere, also *Artisia transversa, Sagenaria rimosa, S. aculeata,* and *S. rugosa.* In Lower Silesia *Stigmaria ficoides* is indeed still more commonly accompanied by *Calamites cisti, Calamites cannæformis,* some Asterophyllites, above all by ferns, like *Neuropteris gigantea, Sphenopteris latifolia, Sphenopteris acutifolia, Lycopodites phlegmarioides, Sagenaria aculeata, Sagenaria rugosa, Sagenaria rimosa.* In the carboniferous sandstones we most commonly meet with *Calamites cannæformis*; *Artisia* is here the greatest rarity. The limestone beds in Lower Silesia, belonging to the coal-formation, also possess their peculiar flora. Upper Silesia does not contain such beds.

8. The different coal-seams, together with the beds above and below them (their roof and floor), must therefore be considered as formed at distinct times, though all belonging to the same formation. This the vegetation contained in them, which differs only in the species and not in the genera, decidedly proves.

9. In Upper Silesia I have as yet only found petrified wood, in a single locality, and that not in the coal itself, but in the sandstone of the roof in the formation at Janow near Myslowitz. On the other hand, upright Sigillariæ and Lepidodendreæ (Sagenariæ) filled with a substance different from that of the including rock, are not rare above the coal-seams.

In Lower Silesia petrified stems are more abundant in the sandstone, in several points, as well in the Waldburg as in the Neurod districts, and upright trees, mostly Sagenariæ, more rarely Sigillariæ, are, if possible, more common than in Upper Silesia.

10. Although the, with few exceptions, horizontal, or slightly inclined position of the Upper Silesian coal-seams, points to a very quiet, slightly disturbed deposition of the vegetation forming them, either in the place of its growth or not far from its native hills and valleys, and we may be partly inclined to deduce from this its state of preservation, more perfect than has yet been noticed in any other place, still even here diverse conditions must have prevailed during the deposition of the separate beds, affecting the preservation of the plants, since in several places these are no longer observable in the coal itself, as in the Zabrzer district, in the most easterly point of the principal coal-deposit, and the most southern point near Hultschin.

Singularly enough the coal in both these localities is distinguished by its peculiar character when used for technical purposes, as it furnishes the best caking coal. In the Lower Silesian coal, where on the contrary, except Stigmaria, few plants are distinctly preserved, caking coal is much less common. Hence we may perhaps conclude that coal with well-preserved structure is to be regarded as only imperfectly mineralized. In Lower Silesia the formation of the coal has in general taken place under less quiet conditions, or more cor-

rectly, immediately afterwards it was violently disturbed by the porphyries that burst forth in many points of the Lower Silesian coal-basin, and have converted a part of the coal sandstones into red sandstone, which, as well as the porphyry, is entirely wanting in Upper Silesia. Near the points of contact a portion of the coal is even charred, and assuredly the high temperature, even though not above that of boiling water, to which in consequence of this violent catastrophe the coal-beds were for a long time exposed, contributed much to the more complete conversion of the vegetable matter into stone-coal, whence we may easily explain the rare occurrence of vegetable structure in this locality. The remarkable activity of the waters at that period is also proved by the innumerable conglomerates, of all dimensions, found in the carboniferous sandstones, which seldom show the almost uniform fine granular character of the same formation in Upper Silesia. [J. N.]

On the Geographical Limits of the Chalk Formation.

By Leopold von Buch.

[Monatsberichte der Akademie der Wissenschaften zu Berlin, für 1849, p. 117. Compare also, Betrachtungen über die Verbreitung und die Grenzen der Kreide-Bildungen; Bonn 1849. Aus den Verhand. des naturhist. Ver. der Pr. Rheinlande.]

The small extent towards the poles which the chalk formation attains, compared with the Jurassic strata, and still more with the palæozoic deposits, has been regarded by Dr. Boué, not without some probability, as the most ancient known effect of the influence of climate on the fauna of former worlds. In reality the most northerly point on the whole earth in which chalk has as yet been found is, according to Prof. Forchhammer's determination, in the vicinity of Thistedt in Jutland, not quite in 57 degrees of latitude, or in that of Aberdeen in Scotland, of Calmar, Mitau, Twer and Casan. In the British islands the chalk does not reach so far north; the last appears on the south coast of the island of Rathlin near the Giant's Causeway, in the latitude of Apenrade, of Bornholm and of Tilsit. Flamborough Head in 54° is its last appearance in England. In Russia this limit always sinks deeper towards the south. From Grodno, where the chalk still appears in 54°, it runs, as laid down in Murchison's masterly geological map, through Mohilew and Orel, a degree and a half of latitude south of Moscow, and from Simbirsk downwards along the Wolga, even to the Caucasus. MM. Murchison, Verneuil and Keyserling have very unexpectedly discovered this chalk on the banks of the Ural river, ninety English miles below Orenburg, in 51½°. The Muchodjar mountain determines its limits towards the east. The immense extent of Siberia from the Ural to Ochotzk, and from the Altai to the Icy Sea, has now been so minutely and carefully examined by so many mining engineers, naturalists and gold-seekers, that we may well doubt of the occurrence of cretaceous beds in this whole region.

Everywhere along this border only the upper chalk appears, the

strata so peculiarly characterized by *Gryphæa vesicularis*, *Belemnites mucronatus* and *mamillaris*, by *Inoceramus Cuvieri* and *Cripsii*, by *Ostrea Diluvii*, *Terebratula carnea* and *semiglobosa*, by *Ananchytes ovata*, *Galerites vulgaris* and *albogalera*, and similar fossils. Older cretaceous strata first appear only in proportion as we descend towards the south, and in the Caucasus, in Daghestan, these older (*neocomien*) beds, according to the excellent observations of Abich, attain a thickness of nearly 5000 feet. It resembles a mighty wave, sweeping far down from the highest summits of the Caucasus and gradually dying away on the margin of the older formations in the plain [on the north].

Beyond the ocean the cretaceous formations terminate in the Atlantic regions of the United States before they have reached the city of New York, so that their limit scarcely touches the 40th degree of latitude, or sixteen degrees lower than in Europe. In Kentucky and Tenessee it remains below 37°. But it is very different far up on the Missouri; this great river flows uninterruptedly from the foot of the Rocky Mountains for 1400 English miles, through strata of chalk, at least as far as the mouth of the Sioux river. This is the result of the accounts and collections of the Prince of Neuwied and of the reports of the celebrated astronomer Nicollet. In these western parts of America therefore, the chalk formation rises to 50° of latitude, or full ten degrees higher than in the eastern portion. Here also it shows a continuous extension greater than that of any other formation known on the surface of the globe. Captain Fremont saw chalk strata, fields covered with *Inoceramus Cripsii*, on the river Platte, Lieutenant Abert on the Arkansas, and as far as Santa Fe in New Mexico, and Dr. Wislicenus found them also beyond the Rio del Norte near Monterey and Laredo, according to the reports published in 1848 by the Congress in Washington. The Rocky Mountains and their continuation to the east [west?] of Santa Fe in New Mexico, have entirely cut off this cretaceous sea. No trace of chalk was discovered either by Captain Fremont on the Columbia river, or on the Humboldt river in the wonderful "Great Basin" down to the Pacific, or yet by the observant Captains Cooke and Johnston in Sonora and California along the Rio Gila.

Nevertheless the whole of this so vastly extended chalk formation consists only of the upper beds. After very careful and accurate investigation, Sir C. Lyell decided, that in the whole of North America chalk strata from the Maestricht beds down to the gault alone occurred; and Mr. Ferdinand Römer, as the result of his highly valuable and accurate researches in Texas, goes the length of considering all the strata in that region, already so far removed from the Atlantic coast, as entirely of the upper division, and not even once touching on the gault.

This peculiarity is, however, singularly enough limited to North America alone. Even in Mexico deeper beds already appear to occur.

M. Galeotti has brought Trigoniæ from Tehuacan, on the borders of the province of Oaxaca, which he has described as *Trigonia plicatocostata**. This *Trigonia* belongs to the division of the *Trigoniæ*

* Bulletin de Bruxelles, iii. No. 10.

Scabræ of Agassiz, and differs but slightly from *Trigonia aliformis*, Sow. The latter is however characteristic for the middle chalk, *craie chloritée*, as also for the gault. In the middle of the chief Cordillera of Anahuac, twelve French miles north-west from Tehuacan, this shell is so universally abundant and large that it may be regarded as the distinctive mark of the entire formation. One is astonished, he says, to find such immense accumulations of fossil shells, so many fragments of ammonites several feet in diameter, or of gigantic coral stems in this place, so much so that there is perhaps no other place on the surface of the globe where such an enormous mass of organic remains lies scattered over many square miles. Now this *Trigonia* appears again in South America in the mountains of Santa Fe de Bogota, from which M. von Humboldt first brought it to us. The organic remains enclosed in the strata of these mountains of Santa Fe de Bogota prove most decidedly the occurrence of the middle chalk, as I have endeavoured to show in the description of Humboldt's collection of American petrifactions (Berlin, 1839), and as Alcide d'Orbigny has still more fully proved in his no less instructive than masterly work on M. Boussingault's collections. But as the cretaceous formations in New Granada attain a thickness of more than 5000 feet, it is not surprising that the organic remains of the lower cretaceous strata, or the *neocomien*, should also be found in this place. D'Orbigny has described an *Exogyra* from Socorra, which is not distinct from the *Exogyra Couloni* of the *neocomien*. Many specimens of this same *Exogyra* were collected by the late Dr. Meyen on the declivities of the volcano of Maypo in Chili at the height of 13,000 feet, and (badly) figured*. Darwin also† found it on the Portillo Pass in the Peukenes chain, not far from Maypo, but also sixty English miles further north on the Uspallata Pass. The *Exogyra Couloni* or *aquila* is, however, a true and very decided characteristic shell for the *neocomien*.

The fossils collected by Darwin in the mountains above Copiapo, and Coquimbo in northern Chili, and those which Domeyko, Professor of Mineralogy in Coquimbo, has sent to Paris, again belong to newer cretaceous strata, and are found in part also at a distance from it beyond the great knot of transition beds which, along with older rocks, have intruded into the chain of the Andes‡. The most remarkable of these forms is the beautiful univalve, which Humboldt first brought from San Felipe in the south of Quito, near the Amazon river, and which was figured and described by me as PLEUROTOMARIA HUMBOLDTII in the 'Petrifactions,' v. f. 26, first published in 1839. D'Orbigny, followed by Darwin, names it "*Turritella Andii*," but whether correctly is still very doubtful. It appears peculiarly characteristic of the whole southern districts of America. Darwin has found it in abundance in the strata of Coquimbo, on the Rio Claro and near

* Acta der Leopold. Academie, vol. xvii. pt. ii. p. 649. t. 27. f. 5.

† Geol. Observations on South America, 1846.

‡ "Beyond and north of the great, shut in, mountain-basin of Titicaca, composed of older rocks, the trias and carboniferous limestone." (Bet. über die Ver. der Kreide-Bild. p. 27.)

Arqueros, and in like manner above Guasco and near Las Amolanos in the principal valley of Copiapo. This *Pleurotomaria* is always conjoined with the *Pecten*, occurring even in the northern regions between Montan and Guancavelica in such incredible numbers, that it forms fields, nay, mountains of petrifactions, long and very generally known to the natives under the name of "*Choropampas.*" (*Pecten alatus*, Dufresnoyi, d'Orb.) It was this shell also that, in 1761, excited so great astonishment in Ulloa at the great elevation above the level of the sea, at which mountains composed of shells were seen, and this astonishment was repeated in all text-books, till it was discovered that the shells had not necessarily lived at this elevation, but might have been raised up from the depths of the sea. Since *Hippurites organisans* (D'Orb. p. 107, t. 22) occurs with the pecten-strata, it is evident that all these beds in Peru, as at Coquimbo and Copiapo, must be conjoined at least with the gault; a result which is most strikingly confirmed by an *Exogyra* which M. Domeyko has sent to Paris. This is indeed perfectly identical with the *Gryphæa* (*Exogyra*) *Pitscheri* from Texas, already described and figured by Morton, and the position of which above the gault at Friedrichsberg has been very accurately ascertained by Ferdinand Römer.

Lower cretaceous strata, similar to those of Aconcagua, are nevertheless not altogether unknown in the Andes mountains near Lima. The celebrated zoologist Von Tschudi has found, on the eastern declivity of the mountains, between Oroja and Yauti, near Tarma, along with many others, some perfectly characteristic neocomien shells:— *Pterocera Emerici* (D'Orb. p. 216), *conoidea*, Goldfs.; *Holaster dilatatus* and *Holaster complanatus* or *Spatangus retusus*, both identified by Agassiz; *Diadema Bourgeti*, also determined as such in Neufchatel; *Pecten cretosus*, Brgnt. and *Pecten quinquecostatus*.

According to this, the cretaceous formation in South America appears to be developed in an entirely different manner, in much greater thickness and variety than to the north of the Gulf of Mexico, and the agreement with the European cretaceous strata is also much more complete in the Andes. It is, however, highly remarkable, that in North America the cretaceous strata are spread out quite horizontally over immense spaces, and that they consist chiefly of clay and sand, and other slightly coherent masses. In South America we only see black limestones, or compact sandstones, of such consistence, that one often believes them to be pure quartz, as between the Maranon and Lima; along with this, the strata are never horizontal, but always more or less inclined; a disturbed position which they evidently can only owe to powerful disturbing forces. There can be less doubt in regard to this, when it is seen, as Meyen informs us, that the precipitous cone of the volcano of Maypo consists for two-thirds of its height of chalk rich in petrifactions, and that throughout the whole of Chili masses of gypsum, many thousand feet thick, surround the volcanos, and the cretaceous strata first appear quite above them. But when we leave this desolation, the chalk also has vanished. It never reaches the plain of the Pampas on the east; a chain of Devonian strata at the eastern foot of the Andes does not permit it even once to touch on

the outskirts of the vast plains of the Pampas. As little can it extend westwards towards the Pacific Ocean. A considerable elevation on the mountains must be attained before it is met with. What then can induce the chalk to run along, only in the direction of the high mountain ridge of the volcanos, and only in a narrow band, and never to descend into the plains!! In the whole of Brazil, in the wide regions of La Plata, Paraguay, Bolivia, the chalk is never again seen, and indeed does not exist. Is it not like a band of chalk which has been formed along the volcanic fissure of the Andes before the mountains were elevated, perhaps because the slightly concealed fissure had produced the conditions of life and existence for the cretaceous mollusca on a more extensive and easily attainable scale?

Darwin has followed the cretaceous strata to the extreme point of the continent. He saw cretaceous shells in abundance on the top of Mount Tarn 2000 feet high, near Port Famine in the Straits of Magellan, and in 53 degrees of south latitude, and consequently three degrees of latitude higher than on the Missouri. *Ancycloceras simplex*, d'Orb. and *Hamites elatior*, Sow. leave no doubt of the chalk. The Hamite is even, says Prof. Edward Forbes, one of the largest ever seen, fully $2\frac{1}{2}$ inches in its largest diameter. Darwin's discovery probably determines the most southern limit of the cretaceous formations; and hence polar influences may have here also opposed its further extension towards the Pole. [J. N.]

Guide to Geognosy (*Leitfaden und Vademecum der Geognosie*), by B. Cotta. Dresden u. Leipzig, 1847. 8vo. pp. 292.

This work forms the third edition of the author's 'Elements of Geognosy and Geology' (Grundriss der Geognosie und Geologie), but very considerably modified in its arrangement and mode of treatment. It commences with a short sketch of Geognosy, which the Germans limit to the 'Knowledge of the internal structure of the solid mass of the earth'; whilst Geology is the 'Doctrine of the origin of this structure and the investigation of the causes of the present condition of the earth generally.' The first section treats of 'External Geognosy,' or the general structure of the earth, its density, magnetism, temperature, form, and the influence of water, volcanic heat, and organic life on its surface. The second contains 'Internal Geognosy,' or the interior structure of the solid crust of the globe; the third, the 'Doctrine of Rocks (*Gesteinslehre*),' their mineral composition, texture, form and divisional structure. Then follows an account of the general principles of petrifaction and stratification, and of the chief stratified, slaty and massive rocks, with a notice of the nature and theory of veins. To this succeeds an extensive Index or Alphabetical explanation of the common designations of rocks and formations, with references to the works—chiefly foreign and especially German—in which they are more fully described. The whole concludes with three tables showing the distribution of Organic remains, the Succession of rocks in Germany, and a Comparison of the succession in that country with some other regions of the earth.

On the Vein-formations *of the* Erzgebirge. By B. Cotta. (*Leitfaden &c.*, p. 117.)

The mineral veins of the Erzgebirge have for a long period, and especially since the time of Werner, been the object of exact investigation, and many attempts have been made to divide them into formations. A short account of the conditions of these formations, according to the views of H. Müller, may serve as an example of such attempts.

The mineral veins which intersect the Erzgebirge in various directions may be reduced to four large chief divisions, essentially distinguished from each other by their local distribution, their mineralogical composition and their geological age. These groups are:—

1. Veins of the Tin-group.
2. Veins of the Pyritical Silver-group.
3. Veins of the Barytes, Silver and Cobalt group.
4. Veins of the Iron-group.

1. The *Veins of the Tin-group*, taken collectively, form a large band from nine to eighteen miles broad, which beginning on the eastern border of the gneiss district of the Erzgebirge, continues, with few interruptions, in a direction from east to west, through the whole Erzgebirge to the Fichtelgebirge; but in its progress, in consequence of various local conditions, appears more or less perfectly developed, and worthy of being wrought. By far the greater number of these veins have a strike coincident with that of the collective vein-mass, from east to west (Morning and Evening veins), with a dip generally very high, to the north or south. These veins appear sometimes as regular vein-masses from one inch to one fathom (*Lachter*) thick, and with a pretty rectilinear strike and dip, sometimes only as bands of many smaller parallel veins lying close together, or at other times as a network of veins and fissures crossing each other at various angles. The first form occurs in most of the tin-veins in the district of Geising, Marienberg, Johanngeorgenstadt and Eibenstock; the second in the veins in the Sauberg at Ehrenfriedersdorf, and in some veins near Marienberg; the last in the mass of veins (*Stockwerk*) at Altenberg, Zinnwald and Geyer.

A common character of the veins belonging to the tin-group is, that the mass filling them, firmly united to the rock forming the walls, consists predominantly of quartz, with which are conjoined—as vein-stones, felspar, lithomarge, steatite, tourmaline, topaz, apatite, astrite-mica, chlorite, fluor-spar, and scheelite—as ores, cassiterite (tin-ore), mispickel, chalcopyrite, pyrites, black blende, hæmatite, wolfram, and molybdenite; along with which also a multitude of non-essential minerals, mostly belonging to younger vein-formations, as barytes, dolomite, siderite, oligon-spar, calc-spar, amethyst, picrolite, nacrite, specular iron-ore, psilomelane, native bismuth, bismuthine, stibine, and uranite, occur in more or less abundance.

According to the local conditions in which the veins appear, sometimes one, sometimes another of these minerals exists in greater abundance; several are often entirely wanting, a circumstance which ap-

pears to have given occasion to Freiesleben to divide this group into several formations, which however are nothing more than various degrees of development in one and the same fundamental character.

The tin-ore is usually disseminated in minute points or grains, more rarely in massive portions in the substance of the vein, but has often penetrated into the walls of the vein, sometimes in such a manner that it is rather the neighbouring rock than the proper vein itself which is worth working.

In the mines at Altenberg the porphyry forming the walls of the vein-mass itself contains tin, and it would appear that the metal has crystallized out of the rock into the fissure of the vein.

In some districts, as at Marienberg, Annaberg, and Oelsnitz, in veins of this group, the tin-ore becomes less predominant, whilst mispickel (Arsenkies), black blende, chalcopyrite, redruthite (vitreous copper), bornite, malachite, black copper and kupferpecherz associated with chlorite, appear in greater profusion; so that the veins assume entirely the character of the Seifen formation of Freiesleben.

Other veins of this group, namely those north from Marienberg, and some near Annaberg, Geyer and Schneeberg, produce particularly much mispickel, black blende, chalcopyrite, and pyrite; sometimes also galena, but very little or no tin-ore. These appear in some measure as connecting members between the pure tin-veins and the veins of the pyritous-lead formation at Freiberg. The Thalheim formation of Freiesleben belongs to this class.

The veins of the tin-group, the number of which surpasses 400, are the oldest in the Erzgebirge. They traverse granite, greenstone, and often also porphyry; but sometimes they are themselves intersected by porphyries.

2. The *Veins of the Pyritical Silver ores* are the most important veins of the Erzgebirge. They are particularly numerous and fully developed in the vicinity of Freiberg, and form together a large band of veins (*Gangzug*), which extends from the left bank of the Elbe, near Meissen, in a direction from north-east to south-west, past Freiberg and Nossen, as far as Langenau and Oederan, and finally appears in the district of Wolkenstein and Drehbach.

Quartz, diallogite and dolomite (brown-spar) associated with mispickel, pyrite, black blende and argentiferous galena, form the characteristic materials filling these veins, with which noble silver ores are more or less commonly associated. But the abundance of these minerals varies in the different districts; sometimes quartz, sometimes pyrite, mispickel and blende, sometimes dolomite and diallogite, are the prevailing contents of the veins, and hence this group has been divided by Von Herder into the three following formations: *a*, the noble quartz-formation; *b*, the pyritical lead-formation; and *c*, the noble lead or dolomite (brown-spar) formation.

a. The noble Quartz-formation (the Braunsdorf formation of Freiesleben) is especially developed to the north and west of Freiberg. The veins belonging to it, of which 150 more important ones are known, form a long band about four and a half miles broad and fourteen miles long between Nossen and Oederan. Their strike is mostly parallel

to the chief direction of the band from north-east to south-west (Standing and Morning veins). Their dip is usually to the north-west. This formation appears in a more isolated manner in some veins in the neighbourhood of Frauenstein, Ammelsdorf, Höckendorf, and Dippoldiswalda.

The thickness of the veins belonging to this group varies generally between one-tenth of a fathom and a fathom; some of them have been examined and found rich enough to be worth working for more than 800 fathoms in length and above 200 fathoms in depth. In them crystalline, or hornstone-like, white or grey quartz forms the predominant filling mass, in which weisserz (argentiferous mispickel), mispickel (without silver), pyrite, blende, galena, but especially the noble silver ores, as the pyrargyrite, argentite, and native silver, frequently occur.

Dolomite, diallogite and calc-spar are also by no means rare, though far from occurring in such abundance as quartz. Less common and always newer constituents are: fluor-spar, barytes, siderite, strontianite, celestine, gypsum, silver-fahlore, fahlore, miargyrite, stephanite, polybasite, freieslebenite, earthy sulphuret of silver (*Silberschwarz*), fireblende, redruthite, marcasite, brown blende, bournonite, stibine, valentinite, kermes, plumosite, hæmatite and specular iron-ore.

The quartz of these veins is in general firmly attached to the walls, and frequently encloses fragments of them, which it has surrounded with spheroidal zones of crystals. These veins are very frequently broken up into a multitude of branches, and the numerous veins of the Neue Hoffnung Gottes at Braunsdorf are so remarkable in this respect, that they appear to consist only of a vast network of the most variously ramified masses.

The veins of the noble quartz formation are the oldest in the vicinity of Freiberg; some of them, as the Reinsberg Gluck-Morgen vein, are traversed by porphyry.

b. The pyritical Lead-formation (the Züg, Tuttendorf, and Lössnitz formation of Freiesleben) is especially developed in the neighbourhood of the town of Freiberg and to the north-east of it, chiefly in veins, with a strike from north-north-east to south-south-west, and with a dip to the north-west.

The veins have a rectilinear course, are from two inches to half a fathom wide, and not much divided. They consist predominantly of quartz, with thickly disseminated pyrite, mispickel, black blende and galena, with one to six ounces of silver in the hundredweight; but the following minerals also often appear in them: dolomite, diallogite, siderite, fluor-spar, barytes, calc-spar, chlorite, chalcopyrite, pyrargyrite, silver-fahlore, argentite, earthy sulphuret of silver, polybasite, native silver, cerussite, and pyromorphite. To the east and south-east of Freiberg (for instance in Gottlob Spat near Junge Hohebirke), and also in the district of Hohnstein, a number of veins of this formation occur, which besides pyrite, mispickel, blende and galena, frequently contain also chalcopyrite, redruthite, bornite, fahlore, azurite, chrysocolla, malachite, cupreous limonite, cuprite and native copper, and thus exhibit the characters of the Freiberg and Hohenstein formation of Freiesleben, or Werner's copper formation.

Some of the veins of this group contain in the upper parts predominantly iron-ores, as hæmatite, specular iron-ore, and limonite, forming the *eisernen Hut* of the miners.

The veins of the pyritical lead-formation, above 300 in number, appear rather younger than the noble quartz formation; they everywhere intersect the porphyries.

c. *The noble Lead-formation or Brown-spar formation* (the Bränder and the Scharfenberg and Drehbach formations of Freiesleben) occurs with especial frequency in the veins south-west from Freiberg, near Brand and Erbisdorf; and in a more isolated manner in the district of Scharfenberg and Drehbach. In the majority of cases the veins of this formation appear partly with a strike from north to south (flat veins), partly with a strike from north-east to south-west (as vertical (*stehende*) and morning veins), with a dip, often at a very low angle, to the west and north-west.

The average breadth of these veins, some of which have been followed for more than 500 fathoms in length and 200 fathoms in depth, varies from two to ten inches, but sometimes amounts to one fathom. The mass filling them is especially characterized by dolomite (brown spar), diallogite and quartz, in frequent combination with galena, blende (both of them usually argentiferous), mispickel, pyrite, pyrrhotine, silver-fahlore; besides the following newer formations appear in a more isolated manner in them:—siderite, calc-spar, opal, jasper, barytes, celestine, fluor-spar, conite, nacrite, chalcopyrite, fahlore, pyrargyrite, argentite, native silver, earthy sulphuret of silver, polybasite, stephanite, plumosite, hæmatite, stilpnosiderite. The following are very rare: freieslebenite, pyromorphite, cerussite, pechurane, native arsenic, realgar, and kerate. These constituents of the veins often show a simple, often a repeated symmetry, in this manner, that quartz with non-argentiferous galena, blende, mispickel and pyrite form the outer (older) band, nearest the walls; diallogite and dolomite, or brown spar, with the above ores, but argentiferous, and also silver-fahlore, the next following band; and siderite, barytes, fluor-spar, calc-spar, pyrargyrite, argentite and native silver, the inner (newest) band.

In regard to their age, these veins come after those of the noble quartz-formation, but pretty near or very little after those of the pyritical lead-formation. They intersect the porphyries. As yet about 340 more important veins are known, belonging to the brown-spar formation.

3. The *Barytes, Silver and Cobalt group* is the most widely extended and numerously represented group of veins in the Erzgebirge; for more than 1200 veins belonging to it are distributed over the whole Erzgebirge, wherever its crystalline, massive and schistose rocks extend. They are especially frequent and perfectly formed in the vicinity of Freiberg, Marienberg, Annaberg, Joachimsthal, Johanngeorgenstadt and Schneeberg. In their strike two chief directions may be observed, namely from north-north-east to south-south-west, and from east-north-east to west-south-west.

The mineralogical composition of these veins is remarkably variable, and in some districts is altogether different from that in others. This

has given occasion to Freiesleben to divide them into not less than nine distinct formations,—(those of Pöbl, Glashut, Halsbruck, Annaberg, Zschoppau, Johanngeorgenstadt, Schneeberg, Oberschlema and Bockau). As a common character may be mentioned the frequent occurrence of barytes, of noble silver-ores (pyrargyrite, argentite, earthy sulphuret of silver, polybasite, stephanite, native silver), and of cobalt ores (smaltine, chloanthite), with which are usually associated ores of nickel and bismuth (nickeline, rammelsbergite, native bismuth). But in many of these veins the barytes is destroyed and has been expelled by quartz, as for instance in most of the Schneeberg cobalt veins. With the barytes and quartz there is very often associated also fluor-spar, dolomite and calc-spar, along with non-argentiferous galena, brown blende and marcasite; sometimes fahlore and chalcopyrite also occur in great abundance. Rarer minerals are: siderite, conite, pinguite, pseudo-apatite, glagerite, nacrite, gypsum, kerate, realgar, fire-blende, arsenic-glance, native arsenic, bismuthine, uranite, native copper, cerussite, pyromorphite, stibine, plumosite, galmei, thraulite, stilpnosiderite, psilomelane, specular iron-ore, götheite, hæmatite and limonite.

The texture of these veins is often in layers with repeated symmetry; the layers are, however, occasionally broken and again cemented together, when the texture appears brecciated.

In the country round Freiberg the veins of this group consist for the most part of barytes and fluor-spar, and besides fahlore, also frequently yield noble silver ores, but on the other hand only very rarely ores of cobalt, nickel and bismuth; in the veins in the district of Marienberg, Annaberg, Joachimsthal and Johannsgeorgenstadt, quartz has already become much more abundant, and cobalt, nickel and bismuth ores occur almost as frequently as the noble silver ores; in the veins near Schneeberg again the barytes is almost entirely expelled by quartz, and the cobalt, nickel and bismuth ores are by far the most predominant.

The Voigtsberg formation of Freiesleben, developed in several veins in the Voigtland, and especially characterized by chalcopyrite, malachite, limonite and siderite, with quartz, barytes and fluor-spar, appears to be only a modification of the group now described produced by local circumstances.

The veins of the barytes, silver and cobalt group are more recent than those of the tin and of the pyritical silver group. The time of their formation coincides, it would appear, with the period of the basalt, as they intersect the basalt, but have been observed to be intersected by it on one occasion.

4. The *Veins of the Iron-group* (Freiesleben's Rothenberg, Aue, and Schellerhauer formation) form a large zone of veins from five to nine miles broad, which runs along the highest ridge of the Erzgebirge from E.N.E. to W.S.W. Their strike is at right angles to the direction of the zone, or from N.N.W. to S.S.E., and their dip usually very steep, partly to the west, partly to the east. Their thickness is usually from six inches to a fathom, but sometimes even three fathoms. The mass filling them consists of quartz, amethyst, hornstone, iron-flint, barytes

and decomposed felspar, with all kinds of hæmatite, psilomelane, limonite, yellow ochre, specular iron-ore, stilpnosiderite and decomposed manganese ore. Rarer substances are: lithomarge, calcedony, agate, opal, alumocalcite, fluor-spar, calc-spar, pinguite, siderite, clay ironstone, polianite, uranite, and even fragments of anthracite.

These veins, of which about 200 are known, often separate into several parallel chief vein-masses (*Haupttrümmer*). Some of the leading zones can be followed for from five to seven miles in length.

The veins belonging to the iron-group are the most recent vein-formations of the Erzgebirge, for they intersect veins of all the previous groups. The process of filling them is occasionally going on at present by deposition of the hydrated peroxide of iron from warm springs, whereas the formation of the other groups has certainly been long ago completed.

Iron is such a universal constituent of the mass of the earth, that we may probably assume that the formation of ironstone veins has taken place at all times and in many different ways. If this is the case, then some of them must be equal in age to the most ancient of other veins. In reality, examples of this are furnished by the so-called *eisernen Hut* (iron-covering) of many silver ore veins, which, for instance at Przschibram, is partly wrought for ironstone; and the siderite veins, often partially changed into limonite, may also be included. It is not improbable that the ironstone veins generally may be considered as the original outcrop of the other vein formations, in such manner, that, where they appear alone, we may suppose other vein-formations to exist at very great depths, which of course does not prevent many superficial fissures from being filled only with ironstone.

It is not improbable that most of the mineral veins in other regions might be coordinated with these of the Erzgebirge. The materials for doing so however do not as yet exist. [J. N.]

On Vegetable Remains in the Salt-rock of Wieliczka.

By Professor Göppert.

[Arbeiten der Schlesischen Gesellschaft.]

Dr. Göppert has obtained several remains of fossil plants from the salt-mines of Wieliczka, among others, nuts of *Juglandites salinarum*, Sternb., and a new species; three kinds of coniferous wood, like that of the brown coal; pine-cones, probably of two species, similar to the existing *Pinus Pallasiana*, Lamb., and related, together with one of the kinds of coniferous wood just mentioned, to the cones and wood, *Pinites ovoideus* and *Pinites gypsaceus*, discovered by him in the gypsum formation of Upper Silesia at Dirschel and Czernitz. The intimate connection of the gypsum beds of that district with the salt formation has been long known, and similar strata alternate with it in other places; but this proof from fossil plants may confirm this view still more. [J. N.]

TRANSLATIONS AND NOTICES

OF

GEOLOGICAL MEMOIRS.

Experiments on the Formation of Coal, and on the Origin of Fossil Resins. By Professor GÖPPERT.

[Arbeiten der Schlesischen Gesellschaft in J. 1847, p. 70.]

LAST year I directed the attention of the Society to the successful results of some attempts which I had made to form coal by means of moisture, the plants employed in these experiments having been placed for a long time in water, to which air had access, and whose temperature was maintained during the day at 80° R. (212° F.), and at 50° to 60° R. (135° to 167° F.) during the night. In this manner there was obtained from many plants even in one year, from others only after two years, a product which in its external aspect could not be distinguished from brown-coal; but by this process even in two and a half years I could not obtain a substance similar to stone-coal, or a coal of a black, shining aspect. I only succeeded in obtaining this by adding a small quantity of sulphate of iron, about $\frac{1}{96}$th per cent.; which I did in the belief that the sulphuret of iron, so common in stone-coal, has undeniably proceeded from the plants which have contributed to the formation of the coal.

In these experiments I used the following fresh plants :—

Fronds of *Polypodium effusum*,
„ „ *Pteris nemoralis*, and
„ „ *Cheilanthes repens;*
Aspidium filix mas (fresh stems),
Wood with branches and leaves of *Pinus balsamea*,
Leaves of *Chamærops humilis*,
„ „ *Cycas revoluta*,
„ „ *Lycopodium denticulatum*,—

plants that may be considered as the chief representatives of the ancient flora.

A certain quantity A, with the amount of sulphate of iron-protoxide just mentioned (2 drachms to 6 ounces of fresh plants), and another quantity B, without it, were placed each separately in a peculiar, slightly shut box with water of the temperature stated in the Digestorium of the laboratory of the University here, on the 27th of February 1846. Even in two months a striking change, an incipient brownish-black colouring, was observable on the plants enclosed in the first box A, whilst the others B had scarcely wholly exchanged their green colour for a faded hue; and when I concluded the experiment on the 1st of May 1847, consequently after fourteen months, those in A appeared entirely black, and darker than the

plants mentioned above, which had been digested for two and a half years without the addition of sulphate of iron, whereas those in B only showed a slight tinging of brown.

I am far from believing, as I have often formerly stated, that the plants of the ancient world, either before or after they were entombed in the strata, were exposed to a fluid of so high a temperature, but only mean that the method I employed, which I would recommend to chemists for analysis, especially for geognostic or geological purposes, served to hasten the process of the formation of coal, and specially to compensate for the time, which we, with our transient existence, cannot use in our laboratories. To obtain a more perfect product, it only seemed necessary to combine with this method of experimenting the action of pressure, which would undoubtedly have a very great influence, but which it is very difficult to accomplish.

In the mean time a very intelligible view may be thus obtained of the formation of many fossil resins, which, almost universally originating from Coniferæ, owe their diverse chemical properties, in a great measure at least, to the peculiar circumstances in which they have undergone the process of fossilization, as I have formerly shown, particularly in regard to the mellite which is included in this class of bodies. When I exposed resin of the *Pinus Abies*, L., for three months to the action of warm water under the above conditions, it no longer smelt of turpentine, but had a peculiar and not unpleasant, balsamic odour, though still soluble in alcohol. Venice resin, however, lost this property, at least in part, after being digested in the manner mentioned from the 1st of May 1846 to the 1st of May 1847, or for one year, and thus approximated more to amber, which, as is well known, is almost wholly insoluble in alcohol. These experiments are continued. It is thus not altogether improbable that by suitable modifications of these experiments we may succeed in producing, artificially, many of those resins which properly belong not to the mineral, but the vegetable kingdom, such as retinasphalt, amber, and even mellite. [J. N.]

On the Water contained in Basaltic Rocks.

By Professor J. F. Hausmann.

Water is occasionally found in druses or amygdaloidal cavities of rocks, especially in basalts and basaltic amygdaloids. Stucke examined the water from the basalt of Unkel, on the Rhine, and found in it a small proportion of silica, alumina and magnesia*. The vesicular cavities of some basaltic amygdaloids are not uncommonly filled with water, as I have often observed among other localities in the amygdaloids of the Ochsenberg near Dransfeld. It has been imagined that this water originated from the formation of the rock, but I have no doubt that it is drawn by capillary attraction into minute fissures from the exterior, and thus penetrates into the amygdaloidal cavities. [J. N.]

* Chem. Untersuch. einiger niederrhein. Fossil. 1793, s. 119.

On the Fossil Flora of the Grauwacke or Transition Rocks of Silesia. By Professor Göppert of Breslau.

[Karsten u. v. Dechen's Archiv für Miner. xxiii. pp. 60–72, 1849.]

In carrying out the commission given him early in the year 1844 by the chief surveyor of mines, Count von Beust, to explore Upper Silesia, Dr. Göppert made the grauwacke formation of South Silesia and its hitherto unknown fossil flora his chief object of inquiry, and that, more particularly as, from his acquaintance with these strata and their vegetable organic remains, he had long cherished the opinion that the grauwacke possessed a peculiar flora.

On the Transition Rocks of Silesia.

Of the now subdivided formation, formerly known as transition or grauwacke, we have in Silesia, says Dr. Göppert, in the upper Kunzendorfer strata, perhaps only the newest part of the series, the so-called Devonian, whilst the rest might be regarded as the lowest member of the coal formation, the deposition of which preceded the formation of the coal-measures.

In the whole Leobschütz district, the grauwacke, which is to be regarded only as an outlier of the great mass of the formation in the Austrian Principalities Jagerndorf and Troppau, forms more or less elevated hills capped with clay. On the declivity of the district towards the valley of the Oppa, the summits of these hills, composed of grauwacke slate, are not covered with clay. Natural sections of these rocks appear only in the river-courses, as for example on the Mora, near Castle Füllstein, Fort Meidelburg and other places. Generally the nature of the rock is evident only at the quarries, and these occur more or less plentifully near every village. [The order in which Dr. Göppert visited the quarries in the Leobschütz district and in the neighbouring Austrian Silesia then follows.]

The composition of the grauwacke in this upland-district is very uniform. Two chief varieties are conspicuous, accordingly as the grauwacke is disposed in thick beds or as grauwacke- or clay-slates. The first is generally grey, of greater or less hardness according to the size of the quartz crystals and white mica-flakes, its chief constituents; rarely almost bluish, sometimes reddish from the intermingled feldspar crystals, as near Kreuzendorf.

The beds are of variable thickness, from one or two inches to one and sometimes even ten feet, as in the quarry on the Mora between Grätz and Troppau, which exposes a fine section of from sixty to eighty feet perpendicular height. Very often the strata are horizontal, as in the quarries near Leobschütz, with an inclination towards the east. Towards its termination a stratum usually diminishes in thickness, and the rock, from the preponderance of argillaceous matter, gradually passes into a soft bituminous clay-slate, and the mica-flakes disappear; or the separation of the constituents is more sudden and distinct.

In the thick beds, for instance in the quarries near Troppau, sepa-

rate globular masses are frequently found, either more or less reddened by oxide of iron, or blackened with carbonaceous matter; often concentrically laminated, and of various sizes, sometimes of two feet diameter. The whole mass is often so ferruginous, that, by long exposure to the atmosphere, it will, in the crevices, be coloured red, as in the quarry near Sabschütz, north of Leobschütz. Sometimes also the red oxide of iron is the material of all the foreign bodies contained in the mass, particularly of Calamites. Coal also, generally anthracitic, is found in isolated masses in the quarry of the Spitalmühle, near Berndau. A profusion of globular masses coloured black by carbonaceous matter often produces a change into black or grauwacke-coal-slate; very few thick layers of which are separable, particularly near the surface. This slate consists of equal parts, by weight, of carbon, quartz, and clay, and is nearly always destitute of mica-flakes. A preponderance of quartz gives this slate greater hardness, so that it may be used for roofing-slate, as in a quarry half a league behind Grätz, near Troppau. The quarries in which this slate is worked being situated within the grauwacke district, it may be looked upon as primary clay-slate, unless it here and there exhibits Calamites of a younger age.

These coally or bituminous clay-slates, often containing some lime, have already occasioned experiments in search of coal, as very lately near Tost and in different places near Unter-Paulsdorf in the Leobschütz district. Naturally no coal of workable quality was found, and these experiments only afforded a nearer insight as to the nature of the beds at a greater depth, which at Paulsdorf were very calcareous. Peculiar shell-shaped concretions and also several testacea were brought to light, of which, as they had already again closed the pit, I preserved unfortunately only one specimen, a sufficiently distinct fragment, however, to be recognised as *Lituites convolvens*, Schlot., the occurrence of which is limited to the first transition period. At Tost, indeed, there was also at the place of experiment a great quantity of slates present, mostly slaty grauwacke, which, however, were destitute of nearly all trace of vegetable remains.

Great aggregations of conglomerate, on so grand a scale as they occur for example on the banks of the Bober at Landeshut, in Lower Silesia, are on the whole seldom met with; I saw such on the valley-sides of the grauwacke rocks which are exposed in the village Dirschel. Besides the above-mentioned Lituite, I did not succeed in finding, in the district referred to, any other animal organic remains.

On the Fossil Flora of the Transition Rocks of Silesia.

As to the occurrence of plants in the localities above referred to, they are always sparingly to be met with, and in the conglomerate at Dirschel at one spot only. They are scarcely ever found in the grauwacke that lies in thick beds, but in the laminated argillaceous beds that generally mark the divisions between the thick strata. They occur in extensive layers, especially the more delicate remains, in grey, faintly reddish-coloured clay, and although not in great variety, yet

in such considerable quantity that they sometimes appear entirely to compose the beds in which they occur.

The quarries situated north of Leobschütz, especially at the Steinmühle, near Berndau, as also the three at Kittelwitz, afford the greatest proportion; and indeed from thence I obtained the largest portion of my collection. The grauwacke-slates *proper* on the other hand are very poor, and only here and there have I found Calamites in the black, more or less siliceous or argillaceous roofing-slate, in the quarries half a league behind Gratz near Troppau. The slate quarry at Heinzendorf beyond Olbersdorf, situated within the primary clay-slate district, is quite destitute of vegetable organic remains.

It was most interesting to me to find throughout this district, not only some species generally distributed, but also such as I had hitherto observed only in the allied formation of Landeshut, Glätzisch Falkenberg, Hausdorf and Altwasser, and which it has in common with the oldest coal formation. To these latter belongs *Stigmaria ficoides*, which occurs in the Leobschütz quarries, and at Grätz near Troppau, Mocker, Lasitz and Dirschel, but nowhere so abundant and in such distinct specimens as at Landeshut; but, from the softness of the clay beds, I never succeeded in obtaining a good hard cabinet-specimen. The *Sagenaria aculeata*, Presl, is found in the quarry at Dobrislawitz, on the right bank of the Oppa, right opposite to the Weinberg of Hultschin, also *Calamites cannæformis*; much more plentiful, however, in Landeshut than here. Widely distributed and to be regarded as typical of the Silesian grauwacke are two species, *Calamites transitionis* and *C. distans*, Göpp., the former distinguished by the longitudinal ribs not dying out at, but extending over the joints, the latter by the ribs standing remarkably distant one from another. These have been found in fragments nearly everywhere, and even in quarries destitute of all other plants, as for example, besides the above-cited places, in the grauwacke at Tost. At the same time with these, especially in the soft clay beds, occur delicate linear leaves with parallel veins, of which, however, I found only a few specimens, somewhat perfect, but not once fixed on stalks. I provisionally name them *Nœggerathia pusilla*. Less widely distributed, and found only in the Spitalmühle quarry near Berndau, but occurring more plentifully in Landeshut, is a Calamite, which from its stigmaria-like scars I call *Calamites stigmarioides*; another, long-jointed, no joint being found in a length of a foot and a half; the excessively delicate *Hymenophyllites Gersdorfii*, from the first quarry near Kittelwitz; the *Sagenaria polymorpha*, Göpp., from the Steinmühle quarry near Berndau, occurring also in Landeshut; the remarkable *Pachyphlœus tetragonus* from the third or southernmost quarry near Kittelwitz, and at Dirschel, Mocker, and Lasitz, also in Altwasser and Landeshut. In addition to *Knorria imbricata*, St., from Landeshut, four new and as yet undescribed species of this genus are here noticed.

When the black globular concretions, occurring in the grauwacke, are somewhat compressed, they bear a resemblance to some nut-like fruits, but are quite destitute of anything like organization.

The following is a catalogue of the plants hitherto observed in the

grauwacke or transition formation of Silesia and other countries. Those found out of Silesia are marked thus †.

Cl. I. Plantæ cellulares.

A. Aphyllæ.

1. Algæ.

Chondrites, *Presl.*

†antiquus, *St.* Transition limestone of the Island Linon, near Christiana, Norway.

†circinatus, *St.* Kinnekulle, Sweden.

†Nessigii, *Göpp.* Rammelsberg in the Hartz (*Römer*).

†tenellus, *Göpp.* Schulenberg in the Hartz (*Römer*).

Sphærococcites, *St.*

†dentatus, *St.* Transition limestone, near Quebec, North America.

†serra, *St.* With the foregoing.

Cl. II. Plantæ vasculares.

B. Monocotyledones cryptogamæ.

2. Equisetaceæ, *DeC.*

Calamites, *Succ. & Schl.*

obliquus, *Göpp.* Gl. Hausdorf.

cannæformis, *Schl.* Coal formation of Germany, France, and England; and the transition formation of Silesia.

dilatatus, *Göpp.* Sabschütz, Berndau, Mocker, and Lasitz (near Leobschütz), and Tost; Gl. Falkenberg and Altwasser.

remotissimus, *Göpp.* Kittelwitz near Leobschütz, and Landeshut.

transitionis, *Göpp.* Landeshut, Altwasser, Bögendorf, and Gl. Falkenberg; Leobschütz and Tost.

stigmarioides, *Göpp.* Landeshut; Berndau.

tuberculatus, *Göpp.* Landeshut.

tenuissimus, *Göpp.* Grätz near Troppau.

†Voltzii, *Brgn.* Hundsweiler, Baden.

variolatus, *Göpp.* Landeshut.

Equisetites, *Sternb.*

†radiatus, *St.* Transition formation of the valley St. Amarin on the Upper Rhine.

3. Asterophyllitæ, *Ung.*

Asterophyllites, *Brgn.*

elegans, *Göpp.* Gl. Hausdorf.

†pygmæus, *Brgn. Prod.* p. 150. Transition formation, no locality given.

†Rœmeri, *Göpp.* Rammelsberg in the Hartz (*Römer*).

Bornia, *Sternb.*

Bornia scrobiculata, *St.* Landeshut.

4. Filices.

a. *Sphenopterides*, Göpp.

Hymenophyllites, *Göpp.*

Gersdorfii, *Göpp.* Landeshut.

b. *Neuropterides*, Göpp.

Cyclopteris, *Brgn.*
dissecta, *Göpp.* Gl. Falkenberg.
frondosa, *Göpp.* Mocker and Lasitz.
tenuifolia, *Göpp.* Gl. Falkenberg.
Bockschii, *Göpp.* Gl. Falkenberg.
Nœggerathia, *St.*
ovata, *Göpp.* Kittelwitz.
pusilla, *Göpp.* Kittelwitz, Berndau, Mocker, and Lasitz; and Altwasser.

c. *Pecopterides.*

Cyatheites, *Göpp.*
†asperus, *Göpp.* Berghaupten, Baden (*Brongniart*).
Pecopteris, *Brgn.*
Jægeri, *Göpp.* Landeshut.
5. Stigmariæ, *Ung. & Göpp.*
Stigmaria, *Brgn.*
ficoides, *Göpp.* Gl. Falkenberg and Landeshut. Coal formation.
Ancistrophyllum, *Göpp.*
stigmariæforme, *Göpp.* Landeshut.
minutum, *Göpp.* Berndau.
Didymophyllon, *Göpp.*
Schottini, *Göpp.* Landeshut.
6. Sigillariæ, *Ung.*
Sigillaria, *Brgn.*
†Sternbergii, *Münst.* Grauwacke, near Magdeburg.
undulata, *Göpp.* Landeshut.
†Voltzii, *Brgn.* Transition formation at Hundsweiler, Baden.
minutissima, *Göpp.* Bögendorf, Lower Silesia.
7. Lycopodinæ.
Lycopodites, *Brgn.*
acicularis, *Göpp.* Lower Kunzendorf near Freiburg.
Knorria, *St.*
imbricata, *St.* Landeshut; and about Leobschütz.
†Gœpperti, *Röm.* Grauwacke of the Hartz, between Neuhof and Lauterwerk (*Römer*).
acicularis, *Göpp.* Kittelwitz.
longifolia, *Göpp.* Dirschel.
Schrammiana, *Göpp.* Kittelwitz.
acutifolia, *Göpp.* Kittelwitz.
†polyphylla, *Röm.* Clausthal in the Hartz (*Römer*).
†Jugleri, *Röm.* Between Neuhof and Leiterberg (*Römer*).
†megastigma, *Röm.* With the foregoing (*Römer*).
Sagenaria, *Brgn.*
aculeata, *Presl.* Dobrislawitz.
squamosa, *Göpp.* Gl. Falkenberg.
polymorpha, *Göpp.* Landeshut; and Berndau.
†Veltheimiana, *Presl.* Grauwacke near Magdeburg.

Aspidiaria, *Presl.*
Gœppertiana, *Stiehl.* Grauwacke at Wernigerode (*Stiehler*).
acuminata, *Göpp.* Altwasser.
†attenuata, *Göpp.* Grauwacke of the Hartz (*Römer*).
Pachyphlœus, *Göpp.*
tetragonus, *Göpp.* Landeshut and Gl. Falkenberg; Kittelwitz, Mocker, Lasitz, and Dirschel.
Megaphytum, *Artis.*
Kuhianum, *Göpp.* Dirschel and Leobschütz.
Rothenbergia, *Cotta.*
†Hollebenii, *Cotta.* Grauwacke of the Rothenberg near Saalfeld.

[The last-named species Dr. Göppert believes, from the disposition of the scars, to belong to the genus *Megaphytum*.]

The species here brought forward, although few, about sixty in number, and by no means of plentiful occurrence, yet with few exceptions generally distributed throughout the formation, appear well fitted to be regarded as a peculiar Flora, which we provisionally term the Transition Flora. Unquestionably they deserve a separate monograph, which I have set about publishing, separate from my other works, in a supplemental volume to the 'Nova Acta Acad. C. L. Nat. Curios.' I have had the foregoing paper by me for three years and a half, and delayed its publication until the completion of further researches; but I now publish it, thinking the subject not to be without interest at the present time.

Dr. Göppert concludes by stating, that in the forthcoming extended work on the Grauwacke Flora, he intends to include not only an account of the fossil plants of the Silesian grauwacke, but of that of other countries, on which subject he will be glad to receive communications; that H. v. Stiehler of Wernigerode has communicated some new species from the grauwacke-slate of that place; and that lately in the grauwacke of the Rhine province, previously regarded as destitute of fossil vegetable remains, he has observed, near Horbausen and near Coblentz, a new Alga, *Haliserites Dechenianus*, Göpp., previously discovered by H. v. Dechen.

[T. R. J.]

On the Results of the latest Researches explanatory of Carbonic Acid Exhalations. By G. Bischoff.

[Leonh. u. Bronn's Jahrb. f. Miner. 1849, p. 725, and Verhandl. der Niederrhein. Gesellsch. zu Bonn, 1849, 23 Feb.]

Bischoff found that carbonic acid was gradually separated from carbonate of lime by silicic acid with the cooperation of boiling water. This decomposition took place, whether the silicic acid was in a soluble or insoluble condition; for even finely pulverized quartz decomposed the carbonate of lime, the process, however, in that case being rather slower. Carbonated oxydule of iron (Spatheisenstein) and the carbonate of magnesia behave in like manner; the latter is decom-

posed even more easily and in greater quantity than the carbonate of lime. The more facile decomposition of carbonate of magnesia is shown by the fact that even boiling water by itself separates the carbonic acid from it, this not being the case with the carbonated oxydule of iron. When, therefore, either limestone, dolomite, or iron-stone-spar occur at a depth beneath the earth's surface where boiling-water-heat exists, and water has access, carbonic acid will be driven off from these carbonated salts.

The Soffioni on Monte-Cerboli, &c. in Tuscany, discharging boiling-hot vapours from crevices in the limestone, must come from a depth where boiling heat exists, and it is very probable that the accompanying carbonic acid arises from the above-mentioned causes. The same must be admitted for the carbonic acid discharged so abundantly in the neighbourhood of the Laacher-See, in the volcanic Eifel, and in other places. These exhalations proceed from the clay-slate formation. According to the laws of the increase of temperature towards the centre of our earth, we may calculate that boiling heat exists at a depth of about 8600′ in these districts, and this depth is certainly within the limits of the clay-slate formation, which is calculated to be at least a mile [German] thick. Calcareous beds (transition limestone) and quartzose rocks occur at this depth, waters penetrate thereto, and carbonic acid is separated from the limestone as in the above-mentioned experiments.

To account therefore for the origin of carbonic acid exhalations, we need no more assume that the focus must be where red heat exists, which presupposes a depth of at least five miles [German]; for the clay-slate or any other sedimentary formation may be the seat of the evolution of the gas, since only in the moderate depth of about half a mile [German] the materials required are present. [T. R. J.]

Account of Mammalian Remains found in the Brown Coal of Bribir, *near* Novi, *on the* Kroatian Coast. By Dr. Moritz Hornes.

[Leonh. u. v. Bronn's Jahrb. f. Miner. 1849, p. 759, and Mittheil. Freund. Naturw. Wien, 1848, iv. pp. 83–86.]

The Vindoler valley extends parallel with the coast of the Gulf of Quarnero 4½ German miles from south-east to north-west. Both of its sides, occasionally very steep, consist of sandstone and clay-slate; these rocks, on one side, are overlaid with limestone, which elsewhere appears to have been washed away by the floods that excavated the valley. In this valley have been found two kinds of coal; glance-coal, pure, thick, very shining, brittle, and exhibiting a transition from brown- to stone-coal; and brown-coal with distinct woody texture, dull, earthy, and brown. Probably the former belongs to the Wiener sandstone, Macigno, or, according to Morlot's latest researches in Istria, to the Keuper; whilst the latter is tertiary. The former lies on a very hard sandstone; and the latter,

forming a stratum $2\frac{1}{2}'$ thick, has above and below it a hard black clay. Here have been found partly in the brown-coal and partly in the clay bed beneath it,—

1. *Mastodon angustidens*, Cuv. A whole upper jaw, with four molars and two fragments of tusks, of a young individual.

2. *Tapirus priscus*, Kaup. Of the upper jaw, one incisor, the sixth and seventh dextral molars; of the lower jaw, the two canine teeth, the first, second, third, and fifth dextral molars, and the sixth sinistral molar.

3. *Cervus*. A molar very similar to the upper molars of the little *Cervus namby*, from the Brazils.

[This reminds us forcibly of Mayence.—Ed. Jahrb.]

[T. R. J.]

Fossil Eggs of Snakes in the Freshwater Limestone at Beiber *near* Offenbach. By Prof. Blum.

[Leonhard u. Bronn's Jahrb. für Miner. 1849, p. 673–675.]

In the mineralogical cabinet of Herr C. Rössler, so pre-eminently rich in the natural curiosities of the Wetterau, I noticed several longish egg-shaped bodies, similar to others that I had previously seen at the house of Herr Witte, at Frankfort. And these were so much the more interesting, as some doubt still existed with regard to their origin; some considering them to be inorganic concretions, whilst others regarded them as organic bodies—fossil eggs of snakes or lizards. But no one can doubt that the latter is the correct idea; for the great uniformity, with respect to shape and size, of the different specimens, and I have seen more than fifty of them, would make them very remarkable as inorganic products, unless this view were supported by other proof. They are 8–10‴ long, and 5–6‴ thick. The ends taper off in so nearly a uniform manner, that one end scarcely appears broader than the other. They are altogether more cylindrical than the eggs of birds. Some specimens are here and there somewhat compressed; which is easily accounted for by the soft condition of the shell in a recent state. Externally the surface is for the most part rough, like a wrinkled skin.

These bodies consist generally of calc-spar; a thinnish rind of which supports the outer surface, whilst the inside is more or less hollow and covered with little calc-spar crystals. Sometimes an elongated calc-spar, stretching from side to side, occupies the egg. In one specimen some of the calcareous matrix, in which the eggs are found, has penetrated into the inside; in another it constitutes the whole substance of the fossil.

The forms exhibited by the calc-spar crystals are a very acute elongated Scaleno-hedron combined with the primary Rhombo-hedron (R^{12}. R), and a less acute Scaleno-hedron with the acute Rhombo-hedron f ($-2R^2.-2R.$).

To enable me to make observations myself on the fossil eggs and the conditions under which they occur, HH. Rössler and Witte had

the kindness to arrange an excursion to the place and show me the exact spot.

These eggs are found in the Tegel-formation of the district of Offenbach, about half a league from thence, not far from the village of Beiber, in the quarries on the road towards Seligenstadt.

A brackish water-limestone, which is hereabout exposed in several quarries, exhibits a stratum of eight to ten inches thick, which is distinguishable by its soft loamy nature from the rock lying above and below it. In this the eggs are chiefly to be met with; for, according to the statement of the workmen, they occur very seldom in the hard strata. The whole rock belongs to the Paludina limestone, since *Paludina acuta* (*Littorinella acuta*, Al. Braun) composes chiefly the mass. These little shells are here always enveloped in a calcareous coating, and are held together by a more or less pure calcareous matrix, so that the rock has a more or less oolitic appearance. At isolated spots calc-spar traverses the rock in lines, or disposes itself in druse cavities, in columnar spars, or in crystals. The limestone is partly white, partly more or less coloured yellow by hydrated oxide of iron. Sometimes the colour is arranged in stripes, which traverse the eggs also, when the latter are filled with the matrix.

The stratum that contains the eggs is moist, and so soft that large pieces can with difficulty be removed; by exposure to the air it becomes somewhat harder and gradually becomes white and chalky. The eggs occur in this bed either singly or in groups. There are found also both in this softer, as well as in the harder part of the rock, a large *Helix*, perhaps *H. Mattiaca*, Steininger, and more plentifully a small *Helix*; also *Clausilia bulimoides* and *Dreissenia Brardi*.

From what we have said of the characters and contents of these fossils and of the conditions under which they exist, it results that all idea of their inorganic concretionary origin must fall to the ground. Concretionary bodies are formed from within outwards, but here exactly the opposite has taken place; lime in solution has permeated the parchment-like shell of the egg and has been gradually deposited on its inside, and thus preserved the form of the egg after the organic substance itself had disappeared.

I consider therefore these fossils to be the eggs of snakes, perhaps of a Coluber; they are, however, somewhat too large for eggs of the Colubers or lizards now existing in the neighbourhood.

Lizards lay their eggs in warm sand, but many snakes lay them in moist ground or mud, even under water. Such animals could have lived here, on the banks of the Maine and the Rhine, and have deposited their eggs in the calcareous mud, where perhaps an increase of calcareous matter not only prevented the hatching, but furthered the petrification of the eggs. [T. R. J.]

On the Remains of Vertebrata from the Wiener *Basin.*

By Dr. Moritz Hornes.

[Leonh. u. v. Bronn's Jahrb. f. Miner. 1848, p. 751, and Mittheil. Freund. Naturw. Wien, 1848, iv. pp. 176–178.]

The following were collected by Herr Joseph Poppelack, of Feldsberg:—

1. From the Loess at Feldsberg, several teeth of *Equus caballus* and *Rhinoceros tichorhinus*;—between Rabensburg and Hohenau, teeth of *Equus caballus*, *Bos priscus*, and a fragment of an antler of *Cervus euryceros* (a tusk of *Elephas primigenius* also had previously been found there).

2. From the tertiary sand and gravel between Hobersdorf and Kettlasbrunn, near Wildersdorf, two teeth of *Dinotherium giganteum* and one of *Acerotherium incisivum*. A yellow colour, staining the inside, distinguishes the tertiary from the Loess teeth, as Morlot observed (Wien. Mitth. III. B. p. 492); the same condition distinguishes the teeth of the *Acerotherium* from the similar teeth of the *Rhinoceros tichorhinus*.

3. From the Leitha limestone of Garschenthal, between Feldsberg and Steinabrunn, a tooth of *Halianassa Collinii*, Meyer (remains of which have hitherto been found only in the tertiary sand of Linz and in the millstone molasse of Wallsee); teeth of *Oxyrhina xiphodon*, Ag., *O. Desorii*, Ag. (found also at Wallsee), *Galeus aduncus*, Ag., *Lamna elegans*, Ag., and *Myliobates Haidingeri*, Münster.

4. From the caverns of Vepusteck and Beziskala, near Adamsthal, north of Brünn, teeth and fragments of jaw-bones of *Ursus spelæus* and *Equus caballus*.

Dr. Hornes adds also a description of a fragment of a jaw-bone of *Cervus haplodon*, Meyer (Jahrb. 1846, p. 471), from the Leitha limestone, to which species also belong the teeth that Partsch (Jahrb. 1847, p. 578) ascribed to *Palæomeryx Kaupii*, Meyer.

[List of other species of Vertebrata found in the Diluvial and Tertiary Beds of the neighbourhood of Wien (Jahrb. 1847, p. 577–580).]

(*Anthracotherium Neodstadtense*, Partsch.) Brown coal.
(—— *Vindebonense*, Partsch.) Tertiary sand and gravel.
(*Hippotherium gracile.*) Tegel formation; and bed lying on brown coal.
(*Hyæna spelæa.*) Diluvium.
(*Mastodon angustidens.*) Tertiary sands and gravels; and Leitha limestone.
(*Palæotherium Aurelianense.*) Leitha limestone.
(*Rhinoceros incisivus.*) Bed lying on brown coal; millstone molasse; tertiary sands and gravels; and Leitha limestone.
(Vertebræ of Cetacea.) Tegel formation.
(Teeth and Bones of Ruminants.) Leitha limestone.
(*Emys Loretana*, Meyer.) Leitha limestone.
(*Psephophorus polygonus*, Meyer.) Tertiary sand below the Leitha limestone. [T. R. J.]

TRANSLATIONS AND NOTICES

OF

GEOLOGICAL MEMOIRS.

A. Th. v. Middendorff's Sibirische Reise. (*Fossile Fische, bearbeitet v.* Johannes Müller), St. Petersburg, 1847.

[Description of fossil fish from Siberia, by J. Müller.]

The impressions of fish from Siberia, which are the object of the present memoir, occur in a thick grey shale, which besides the carapace of a crustacean, also contains remains of the larvæ of insects and a Helix. The shells represented of the natural size at pl. 11 *, fig. 6. are the most abundant. They have no resemblance whatever to the shells of bivalve mollusca, either with regard to their general form, their extraordinary thinness, or their microscopical structure; they have however the most complete analogy with the shells of certain crustacea, particularly the genus *Limnadia*. I have compared slices of the fossil shells with those of *Limnadia* under the microscope, and find them to agree in every respect. These fossil shells therefore undoubtedly belong to a crustacean closely allied to this genus, if not indeed identical with it. This is a circumstance of great importance in deciding the nature of these shales, inasmuch as the existing *Limnadiæ* live in fresh water. I should not, however, have considered the resemblance of these shells to those of *Limnadia* sufficient to prove this to be a freshwater formation, had not Herr v. Middendorff lately informed me of the facts long ago observed by him, which had convinced him when in Siberia that this was a freshwater deposit. First, the occurrence of the hind-body of the larva of an insect decidedly belonging to the Neuroptera, but which cannot be referred to any of the existing genera of that division, as the three long feathers at the posterior extremity resemble *Ephemera*, while the processes of the body-rings at the side of the abdomen remind us of *Libellula* and *Æschna*. Secondly, the occurrence of a mollusk having a very great resemblance to *Paludina*. Herr v. Middendorff informed me that he had seen in Siberia a specimen of shale, in which, together with impressions of fish, a shell (chiefly as casts) occurred closely resembling a *Paludina*, particularly a half-grown *P. vivipara*. Amongst the specimens of shale with impres-

* The plate does not accompany this Translation.

sions sent to me by M. v. Middendorff, is one containing a specimen of this mollusk. Dr. Troschel, to whom I submitted it, decided that the shell in question could not be distinguished from *Paludina*. Under these circumstances it may be assumed as certain that the beds in question belong to a freshwater formation, and it is at the same time highly probable that they are tertiary.

This conclusion is the more satisfactory, as the fish-impressions themselves are not of such a nature as to give any certain data respecting the age of the formation. It is true that the character of the fish in the above remains at once reminds us of the fish of the class Teleostei, which first make their appearance in the history of creation in the chalk, and are the prevailing forms amongst those now living as well as in the tertiary formations. At the same time the fish of these shales have some resemblance to certain species of *Thrissops* which occur in the lithographic shales, particularly to the *Thrissops cephalus* of Agassiz, at least in the position of the fins, the great number of gill-rays, in the structure and number of the vertebræ, and in the scales. This resemblance has been already noticed by Count Keyserling. The genus *Thrissops*, which belongs to the Ganoid family, is only slightly characteristic of the Ganoid form; so little indeed, that in their general features they are closely allied to the forms of the Teleostei, which have not yet been recognized in the lithographic slates.

If we had not possessed the above-mentioned proofs, which unequivocally show that these are freshwater shales and of the tertiary age, we might have been led by the resemblance of our fish-impressions to the *Thrissops cephalus* to regard them as older. But as the *Thrissops* has not been found in any formations newer than the lithographic shales, we must be careful not to attach too much importance to the analogy of form and structure of the fins, and it is therefore desirable to establish a new generic name for the Siberian fish, which are undoubtedly Teleostei.

It would also appear that the genus *Thrissops* should be subdivided into two distinct genera; for the *Thrissops cephalus* of Agassiz and a few other species, not possessing *ossa interspinosa* on the finless portion of the back, do not appear to belong to the same genus *Thrissops* which contains species with *ossa interspinosa* on that portion of the back, and which, as it appears, have also fulcra for the fins, a feature possessed neither by the *Thrissops cephalus* nor by the small fish discovered by Herr v. Middendorff.

Whatever name may be given to the *Thrissops cephalus* and its allied species which must be separated from *Thrissops*, there are very sufficient reasons for not uniting them with the genus of the Siberian fish. I must not omit to observe, that amongst the genera of living fish there is none to which the Siberian fossil fish can be referred. In order to designate this genus I have chosen the name *Lycoptera*, to signify that the fins are placed in the same way as in the Pike.

Lycoptera Middendorffii, Müll.

Description.—The head is equal to one-fourth of the whole length

of the fish. The jaws are provided with very small, and often scarcely visible teeth. The number of streaks on the skin by the gills seems to be considerable; in some specimens eight to twelve could be distinctly seen, and there may have been more of them. The dorsal fin is placed over the anal fin; it commences behind the anal fin, and has ten soft or articulated rays. The anal fin, of similar construction and form, has fourteen. The ventral fins are abdominal, halfway between the root of the ventral fins and the anal fin. The tail or caudal fin is forked, with equal upper and lower lobes. The ray-joints of the caudal fin are three times as long as they are broad. There are about forty or more vertebræ. When they are so displaced that the sides of the joints are visible, they appear, as in the case of the *Thrissops* of the lithographic slates under similar circumstances, like rings filled up with stone. The end of the vertebral column rather approaches the upper lobe of the caudal fin. There are twenty pairs of ribs, all comparatively thin. The scales are round, extremely thin, $\frac{1}{3}$ to $\frac{1}{5}$ of a line in size, and show when magnified obscure concentric lines on their upper surface.

The size of the fish is 2 inches and upwards. In the shale are impressions of much larger but similar fish, but of which the fragments are too small to allow of any description.

The Siberian fish belong to the order Physostomi of Müller. It is impossible to give the family of the fish with any certainty, although it is probable that they belong to the family of the Esoces.

On one of the slabs of shale is the jaw of another fish, with comparatively long, pointed, and curved teeth, represented in pl. 11, fig. 3, and magnified twice the natural size.

Pl. 11, figs. 1, 2. *Lycoptera Middendorffii*, twice the natural size.

Appendix respecting the locality where the Fish-impressions were found. By Herr v. Middendorff.

By some mistake Prof. Müller appears not to have received a notice I had prepared respecting the locality of the above-described fossil fish, I therefore insert it as an appendix.

These fish-impressions are the same as those to which I alluded in my last notice from Siberia, addressed to the Academy (Bulletin, p. 14), and for which I am indebted to the zeal of Mr. N. A. Sensinow. Mr. Sensinow gave me the following information respecting their site:—About 140 to 150 wersts S. of Nertschinsk, and distant about 70 wersts from the nearest point of the Chinese frontier, the little river Byrka (probably the Mongolian name for an inapproachable spot) falls on the right bank into the Turga, and about 40 wersts above the spot where the Turga itself falls into the Onon, also from the right bank.

Upwards from the above-mentioned mouth of the Byrka, a slaty clay forms the right bank of the Turga, which has cut for itself a deep and narrow bed in the clay. About six feet below the surface of the slaty clay, and in the clay itself, are found the impressions above described by Prof. Müller. Fish and shells all lie together,

and not in separate layers, yet so that while shells occur at the very edge of the bank, fish are found by digging further inland.

The crustacea however (*Limnadiæ*) are found at another portion of the bank in question (probably the site of an ancient pool). The slaty clay has not yet been dug through, but extends uniformly downwards without any alteration. The upper layers are somewhat greasy, perhaps from the remains of decomposed fish.

About 40 wersts to the south of this locality commence the broad endless plains of the Mongolian steppes.

On the right bank of the Onon, about 30 wersts above the mouth of the Turga, impressions of fish are also said to occur; according to report, moreover, the slate is there full of little flakes of mica.

[W. J. H.]

On the Formation of Dolomite. By Prof. G. Forchhammer.

[Oversigt over det Kongelige Danske Videnskabernes Selskabs Forhandlinger, p. 83–96, June 22, 1849.]

Since Dolomieu first paid attention to the magnesiferous limestone of the Alps, called after him *Dolomite*, this rock has often been an object of research; but only after L. Von Buch had pointed out the important part it plays in the Tyrol Alps and at several places in Germany, has its influence on the geological history of the earth been fully recognized.

Carbonate of lime and carbonate of magnesia occur in the earth mixed in various proportions; but nomenclature as yet has in nowise determined to which combinations the terms "common limestone," "dolomitic limestone," and "dolomite," should be respectively applied.

We have here to determine the proportions, in excess or otherwise, in which the two isomorphous salts, carbonate of magnesia and carbonate of lime, are combined. The other conditions, hardness and specific gravity, are here of less importance, as they are independent of the quantity of magnesia present. The structure of the stone, I may remark, here as in the case of limestone, can be of little importance for the determination of the different kinds.

Our common limestone contains a very small quantity of magnesia.

Chalk from Alindelille, in the neighbourhood of Ringsted, is composed of—

Carbonate of lime	98·986
Carbonate of magnesia	0·371
Sulphate of lime	0·073
Phosphate of lime	0·045
Silica	0·436
Argilla and iron	0·089
	100·000

It contains therefore about $\frac{1}{3}$ per cent. of carbonate of magnesia.

The limestone from Faxoe contains—

Carbonate of lime	98·246
Carbonate of magnesia	0·924
Phosphate of lime	0·155
Iron and manganese	0·276
Insoluble matter	0·399
	100·000

This contains therefore barely 1 per cent. of carbonate of magnesia.

The shelly Anthracite from the Transition Formation at Bornholm contains—

Carbonate of lime.....	91·62
Carbonate of magnesia.....	1·02
Insoluble in acid, and precipitated by ammonia ..	5·47
Organic matter, water, and loss	1·89
	100·00

Hereto belongs also the Phryganea-limestone from the base of Gergovia, near Clermont, in Central France, which consists of small fresh-water shells, composing the tubular cases of larval insects, similar to the cases constructed by the larvæ of *Phryganea grandis* and other species of this genus at the present day. It contains—

Carbonate of lime	91·52
Carbonate of magnesia	1·01
Insoluble matter	2·24
Iron and manganese	0·58
Organic matter, water, and loss	4·65
	100·00

Other limestones, composed of shells and corals, present similar proportions; the small quantity of carbonate of magnesia present being derived from the organic substances that have also supplied the carbonate of lime.

I have, for another purpose, analysed a large quantity of corals and shells of marine animals with the following results:—

Astræa cellulosa	contains	0·542	per cent.	of carbonate of magnesia.
Myriazoon truncatum	...	0·445	...	...
Heteropora abrotanoides	...	0·352	...	...
Eschara foliacea	...	0·146	...	...
Frondipora reticulata	...	0·596	...	...
Corallium nobile	...	2·132	...	...
Isis hippuris	...	6·362	...	...

If we omit the family to which *Corallium* and *Isis* belong, the proportion of magnesia amounts to about $\frac{1}{2}$ per cent. of the mass of the corals; and when they pass over to the fossil state, it becomes proportionally increased, as the organic constituents disappear.

Of bivalves I have determined:—

Terebratula psittacea	contains	0·457	per cent. of	carbonate of magnesia.
Modiolus papuana	...	0·705	...	...
Pinna nigra, from the Red Sea,	...	1·000	...	...

Of univalves:—

Tritonium antiquum	contains	0·489	per cent. of	carbonate of magnesia.
Cerithium telescopium	...	0·189	...	...

Of cephalopods:—

Nautilus pompilius	contains	0·118	per cent. of	carbonate of magnesia.
Sepia (*ossa Sepiæ*)	...	0·401	...	...

Of annelids:—

Serpula, sp. from the Mediterranean,	contains	7·644	per cent. of	carbonate of magnesia.
Serpula triquetra, from the North Sea,	...	4·455	...	...
Serpula filograna	...	1·349	...	...

If, therefore, we except the *Corallium* and *Isis* family from amongst the corals, and *Serpula* from amongst the other lower, lime-secreting, marine animals, the quantity of carbonate of magnesia, found in these shells, remains in general under 1 per cent. We can, therefore, easily explain why limestones composed of such animals usually contain a similar proportion of magnesia.

If, then, we fix the limit of the proportion of magnesia that a limestone may contain without losing its character of a "common limestone" at 2 per cent., we shall have that limit which is determined by the circumstances under which limestones are naturally composed, namely by the remains of lime-secreting aquatic animals.

If a limestone contains more than 2 per cent. of carbonate of magnesia, I term it "dolomitic limestone." It follows from the above observations that *Serpulæ* can necessarily form dolomitic limestones that are considerably rich in magnesia; the same holds good with *Corallium* and *Isis*, and probably some other families of animals. The exact boundary between the "common" and the "dolomitic limestone" is somewhat loose and arbitrary, as the presence of different species and varieties in greater or less proportions must be usually accidental; and the same may be said of the boundary-line between the "dolomitic limestone" and the "dolomite."

That rock, however, I call "dolomite," in which the proportion of carbonate of magnesia is more than 13 per cent.; and shall hereafter give my reasons for this determination. Thus, then, "dolomitic limestone" will have between 2 and 13 per cent., and "dolomite" above 13 per cent. of carbonate of magnesia.

There are some naturalists who would consider the character of dolomite to be dependent on its granular crystalline structure, as well as on the proportion of magnesia present; but Werner and Hoffman have already a *compact* dolomite, and others follow this example. Dolomite in this respect is subject to the same conditions as limestones; it has its compact and its granular crystalline varieties. Other mi-

neralogists, it appears, will allow the combinations to be of value only for dolomite that contains equal equivalents of carbonate of lime and carbonate of magnesia, or, at least, a very simple equivalent-proportion of the carbonated salts. But, according to a number of analyses I have made, carbonate of lime and carbonate of magnesia are not combined in the compact dolomites in any simple equivalent-proportion, which I have only found in the granular crystalline varieties. One might therefore assume that the compact dolomite is a mechanical mixture of carbonate of lime and carbonate of magnesia, whilst the granular crystalline dolomite is a real double-salt [carbonate of lime and magnesia]; but I have found, especially in the compact dolomite from Faxoe, that this also contains a double-salt of equal atoms of carbonate of lime and carbonate of magnesia, mixed with pure, or nearly pure, carbonate of lime. When indeed I treated this dolomite with acetic acid, it was partly dissolved, and there remained a coarse white powder. The soluble part consisted of—

Carbonate of lime	97·13
Carbonate of magnesia	2·87
	100·00

The insoluble portion, on the other hand, was composed of—

Carbonate of lime	58·58
Carbonate of magnesia	41·42
	100·00

This last proportion almost amounts to equal atoms of the two salts; but still the lime slightly predominates*.

The well-known dolomite from Fullwell near Sunderland belongs also to this group. It behaves in the same manner when treated with acetic acid, a white granular powder remaining in large quantity, the composition of which, however, I have not yet fully examined. And I think it very probable that the compact dolomites are mechanical mixtures of carbonate of lime and a dolomite composed of equivalent proportions of the two carbonated salts.

The next question is of far greater importance, namely the geological relations of the dolomite; but I must here omit to notice some of the most important phænomena connected with the formation of dolomite, as I am but slightly acquainted with the dolomite formation of the Alps, and can hardly assume that I am sufficiently intimate with the disputed and very difficult questions connected with Von Buch's dolomite theory. I intend, therefore, here to treat of the compact dolomite only.

In the course of this summer I have discovered dolomite in the chalk-hill at Faxoe, where it occurs under conditions that are extraordinarily illustrative. The Faxoe limestone [Faxöekalk] lies at Stevnsklint between the writing-chalk, which is the lowest stratum, and from which it is separated only by an inconsiderable clay-bed,

* In order to be in exact equivalent proportions, there should be 54·4 carb. lime, and 45·6 carb. magnesia.

and the limestone [Liimstenen]. There it has a thickness of only a few feet, and is characterized by a quantity of peculiar fossils. In the hill at Faxoe it has a hitherto undetermined thickness, but which, for reasons to be hereafter given, I fix at about 100 feet. For a long time the underlying stratum was not known, and no other overlying stratum but the clay of the gravel-beds [Rullesteens-Leer]; so that, when I first pointed out the true geological relations of the strata, as now usually adopted, I was obliged to support my views by the similarity of the peculiar fossils. Two years since a limestone was discovered in the Toftekule, which, like the upper Faxoe limestone at Stevnsklint, contains its peculiar fossils, and is further characterized by its composition and the subordinate flint beds. The basement stratum is not yet determined with precision; but we have observed chalk at many places around Faxoe, and we may therefore reasonably suppose that the hill itself rests upon a raised chalk plateau. This idea is strengthened by the fact of the base of the Faxoe Hill being surrounded by a circle of springs, that probably have their source between the porous Faxoe limestone and the writing-chalk, which latter, by reason of the closeness of its fine component particles, opposes the further percolation of water.

At a spot in the Toftekule, between the limestone and the Faxoe limestone, a perfectly distinct bed, composed of a yellow calcareous sand [Kalksand], intrudes itself, and in this stratum globular masses of dolomite occur. These bodies frequently attain more than a pound weight, and are often united into irregular masses similar to those with which we are acquainted from other dolomite formations, especially from Sunderland in the north of England. The dolomite contains no fossils, whilst the Faxoe limestone [Faxöekalk], the yellow calcareous sand [Kalksand], and the limestone [Liimstenen], are surcharged with remains of marine animals. I may add, that the flint of the limestone sometimes penetrates the globular dolomite masses; and that there is not found in the whole of Faxoe Hill the least trace of a chemical plutonic action, except its being the seat of springs. The effects of springs that have degraded the calcareous rock are everywhere visible. Wherever the coral-limestone is composed of a mingled mass of sharp-sided fragments, these are superficially covered with a coating of lime, yellow and ferruginous; and at many places the fossils become indistinguishable from a layer of calcareous sinter. The thick limestone strata are perforated by numerous large, perpendicular, tubular holes, having a diameter of 1–2 feet. The workmen call them chimneys; they resemble the hollow pipes that are frequently found in the Danish and English chalk, the origin of which is now usually and with great probability referred to the action of excavating springs.

These springs have formed the dolomite, not by directly depositing carbonate of magnesia brought up from below in a soluble state, but *by the carbonate of lime, held by them in suspension, decomposing the magnesia-salt of the sea-water*. And indeed the globular form always assumed by the Faxoe dolomite is a proof of its formation by means of springs. One cannot indeed well conceive that these glo-

bular masses were formed in any other manner than that in which the Karlsbad pea-stone, confetti di Tivoli, and all similar formations comprised under the term Roe-stone [Rogenstenen], originated.

This is brought about by water in one or two ways; it separates and brings up small particles, around which lime, disengaged by the escape of the carbonic acid, is deposited. As long as these separate particles remain washed about in the water, they must naturally be round, as the isolation is perfect on all sides; but when they ultimately become so heavy that the water cannot keep them in a state of motion and therefore floating, they sink downwards and become united by means of the disengaged lime into connected masses. The formation at Karlsbad takes place in the same manner; and the only variation in the form of the two deposits is, that the Karlsbad pisolite has a conchoidal fracture, which is never found in the dolomite spheroids of Faxoe, nor in that from Fullwell near Sunderland. But there is the great difference at Karlsbad and the other places mentioned, that at the former the spring has a subaërial outlet, whilst the others had submarine outlets; and it is natural that in the first case far more numerous interruptions must occur, as expressed by the conchoidal fracture, than in the last, where the great body of water must make the separations far more regular.

It results from the foregoing, that the size of the spheroids is a measure of the force of the springs; and, for comparison, I will here remark, that the fountain at Tostrup Valdbye, giving 13,000 tons of water per diem from a bore of 6 inches diameter, could keep suspended a fragment of limestone weighing a pound. The spring-pipes at Faxoe have on an average a diameter of at least double this, and their current of water must have been at least four times as strong to have supported the floating dolomite masses of a pound weight. I may also add, that the globular bodies, formed by submarine springs, are easily distinguished from those arising from trituration (Roe-stone); the former are of unequal size on account of the very unequal motion in and near the spring-head; whilst the trituration effected by the waves is uniform. Its form and mode of arrangement distinguish the Faxoe dolomite as having been the result of a submarine spring; and as the underlying Faxoe limestone is a marine formation, and the calcareous sand, in which the dolomite occurs, contains marine corals, and the limestone that surmounts the whole is likewise marine, it is impossible to entertain a thought of these springs having been extra-marine.

It could scarcely be supposed that the springs would have had their issue at the top of the hill, and not, as now, at the foot; but on a closer examination of the various conditions, it will be evident that the springs must have burst from the top of the hill, as appears from the spring-pipes that they occupied. We imagine that fresh water penetrated the Faxoe Hill when the sea still covered the whole formation; and, therefore, that the place, where the springs would issue, would be determined by the greater or less resistance opposed to them. At present the least resistance is where the springs break out at the base of the hill, the counter-pressure there being the at-

mosphere; the whole of the crevices within the hill being occupied by fresh water that resists the upward direction of the currents. If the whole were covered with sea-water, its depth being but slight at the top of the hill, and supposing that the pressure of fresh water within the hill had force enough to keep out the sea-water from all the cracks and clefts of the rock, then, as the height of a column of fresh water within the hill, and that of the sea-water at its base, would be equal in bulk, the difference of the specific gravity of the two fluids would cause the fresh water to ascend in the hill and to burst forth at the top in springs.

We will now speak of the chemical relations. It is very evident that the iron contained in the Faxoe dolomite has been derived from the water of the springs, because all the sinters of that date, like those which are found in the separated concentric layers, the thickest of them being in a semi-stalactitic state, are ferruginous. That, on the other hand, the magnesia of the Faxoe dolomite was not brought hither by the springs, is apparently proved by the fact that the sinter-like masses deposited in the interior of the Faxoe limestone do not contain an essential quantity of magnesia.

The composition of the Faxoe dolomite is—

	I.	II.
Carbonate of lime	80·67	79·89
Carbonate of magnesia	16·48	17·03
Silica	0·81	0·65
Iron (Argilla?).....	2·04	1·29
Water and loss.....		1·14
	100·00	100·00

In the first analysis the lime was not weighed, and the water and loss were not calculated.

The yellow sand-like limestone which contains the dolomite is composed of—

Carbonate of lime and loss	95·75
Carbonate of magnesia	0·64
Ferruginous silica	2·74
Iron	0·87
	100·00

I have at the same time made analyses of the Faxoe limestone and of the upper limestone, both of which contain a very small proportion of magnesia.

We learn then from chemical analysis that all the limestone at Faxoe has been deposited by sea-water by the intervention of animals, and that the dolomite contained in it, and either contemporary with it or of an anterior or posterior date, contains just such a proportion of magnesia as corresponds to that which the marine, lime-secreting animals always contain. The sinter deposited in the crevices of the coral-rock, and derived from the fresh spring-water, contains also only

a small quantity of magnesia. There is deposited, on the other hand, a mixture of carbonate of lime and carbonate of magnesia where the spring-water has come into contact with the sea-water. We can scarcely doubt that the carbonate of magnesia is precipitated by the action of the water of these springs upon the magnesia-salts of the sea-water. To confirm this theory, I have examined into the manner in which mineral springs act upon sea-water. This examination is not finished, and several points remain that are not yet satisfactorily elucidated; but the results already arrived at are quite sufficient to show that the dolomitic limestones and dolomites are formed by this mutual action of the springs and the sea-water.

My first series of experiments relate to the mutual reaction of sea-water and a solution of pure carbonate of lime in water charged with carbonic acid, under different temperatures. The carbonate of lime solution I call, for the sake of brevity, "carbonated lime-water."

1. Carbonated lime-water mixed with sea-water was set in a frigorific mixture until it was all frozen. After thawing, the deposit consisted of—

Carbonate of lime	92·45	100·00
Carbonate of magnesia	7·55	

2. Sea-water mixed with carbonated lime-water stood for eight days in a temperature of between 15° and 20° C. (determined by a thermometrograph); the deposit was composed of—

Carbonate of lime	97·81	100·00
Carbonate of magnesia	2·19	

3. The same mixture at 50° C.—

Carbonate of lime	96·22	100·00
Carbonate of magnesia	3·78	

4. The same mixture at 87° C., in the vapour bath—

Carbonate of lime	87·36	100·00
Carbonate of magnesia	12·64	

5. Sea-water was brought to ebullition, and carbonated lime-water poured into it in a fine stream, so as not to be lost by the boiling:—

Carbonate of lime	87·75	100·00
Carbonate of magnesia	12·25	

6. A similar experiment—

Carbonate of lime	89·64	100·00
Carbonate of magnesia	10·36	

The above experiments are those of a series, in which the greatest quantity of magnesia was precipitated under the given temperatures; but I obtained many less proportions, and these seem partially to be dependent upon the variation of mutual action; insomuch that the longer the inter-action is continued, the less magnesia is proportionally present in the precipitate. In like manner I obtained by evapo-

rating nearly to dryness a mixture of carbonated lime-water and sea-water at a temperature of 90° Centig. and washing the precipitate, a proportion of

Carbonate of lime.....	98·51	100·00
Carbonate of magnesia..	1·49	

This explains why the roe-stones contain nearly pure carbonate of lime, for the chemical action must in their formation have been extended over a long time; and hence it follows that this carbonated lime-water at the boiling-point of water can only deposit a quantity of magnesia below 13 per cent. of the whole compound precipitate: this is my reason for fixing the limit of the "dolomitic limestone."

The next series of experiments relate to the action of the carbonated aqueous solution of lime and soda [natron] on sea-water. This solution was prepared by adding as much carbonate of soda to the usual carbonated lime-water as it could bear without becoming clouded.

In three experiments I obtained, under different degrees of heat between 50° and 100° C., 13·10, 14·85, 27·93 per cent. of carbonate of magnesia. In these also there occurred the same uncertainty of results as in the experiments with the pure carbonated lime-water, evidently occasioned by certain conditions as yet unrecognized. This much, however, results from these experiments, that the carbonated natron-lime-water deposits a greater proportion of the carbonate of magnesia than the pure carbonated lime-water; and whilst the latter precipitates "dolomitic limestone" from sea-water, the former separates "dolomite."

The third series of experiments will serve to determine how some of the best-known mineral springs will act upon sea-water when brought into chemical relation with it. The decompositions were made with the aid of boiling.

Selters-dolomite was composed of—

Carbonate of lime.....	86·55	100·00
Carbonate of magnesia..	13·45	

Pyrmont-dolomite, calculated after the double iron-salt proportion was separated from the carbonated salts—

Carbonate of lime.....	84·38	100·00
Carbonate of magnesia..	5·12	
Iron	10·50	

Wildung-dolomitic limestone is composed of

Carbonate of lime.	92·12	100·00
Carbonate of magnesia..	7·88	

I have never obtained in my experiments dolomites that were as rich in magnesia as they frequently occur in nature; but I also freely acknowledge that my experiments are very imperfect imitations of nature; and with regard to the temperature, it plainly results from the theory, that the springs that now issue out with a heat of 100° Centig. would have a higher temperature if the pressure of the air were stronger, or if they came out under considerable pressure of water,

and the experiments establish that the proportion of magnesia increases with the temperature.

I cannot leave this part of my subject without remarking, that these observations on the Faxoe Hill explain a phenomenon to which I have previously drawn attention, yet without then being in a position to explain it. The stratum, of which Faxoe Hill is a development, is found over a very large portion of the Danish chalk, but in general only with a thickness of two or three feet. At Faxoe it increases to a thickness probably approaching a hundred feet, and it assumes in its physical relations the character of a coral reef. The cause of this local development is proved by the discoveries above given to be owing to the calciferous springs bringing up such an abundant supply of lime for the marine animals; the warmth of the springs, moreover, favouring perhaps the development of the latter.

In many respects, the well-known dolomite from Fullwell near Sunderland is analogous to the Faxoe dolomite. The same spheroidal masses are found at both places; but at Fullwell I have seen them with a diameter of 4 feet. On the other hand the Fullwell dolomite is distinguished by a form that is not found at Faxoe, viz. the so-called "honeycomb-stone," a dolomite that is full of holes that are somewhat regularly arranged like the cells of a honeycomb. These have been evidently produced by bubbles of disengaged carbonic acid gas, and are very important as they here occur in connection with spheroids formed by the action of springs, and therefore explain the origin of the cavities, whilst on the other hand they form the connecting link with the very cavernous dolomite that especially occurs in the geological period now commonly recognized as the Permian epoch, and to which the Ruevakke belongs.

From these observations we can now also comprehend why the formation of gypsum is collateral with that of dolomite. Gypsum having formerly been carbonate of lime from which the carbonic acid was driven out by sulphuric acid, as is now usually accepted by geologists, the carbonic acid so disengaged must, when water was present, have redissolved a quantity of carbonate of lime; and the reaction of this solution on the sea-water must have formed dolomitic limestones. Hereto belongs, for example, the singular dolomite of Stipsdorf in Holstein, which is black and cavernous as a lava, and contains somewhat worn specimens of the fossils of the brown-coal formation, together with our common gravel-pebbles [Rullestene].

Its composition is—

Carbonate of lime.....	80·55
Sulphate of lime	0·95
Carbonate of magnesia.....	7·49
Silica	5·82
Iron and argilla	2·83
Coal, water, and loss	2·36
	100·00

[T. R. J.]

On the Organic Remains from Arzo *near* Mendrisio. By P. Merian.

[Basel. Verhandlung, 1846–8, viii. pp. 31–33, and Leonhard u. Bronn's Jahrbuch f. Mineral. 1849, p. 866.]

Carl Brunner and Rud. Merian have collected from the red and white marble-like limestone of Arzo the following fossils, as determined by the author of the communication. *Lima*, small, and very similar to *L. Hermanni*, Voltz; *Pecten*, internal cast, closely agreeing with *P. textorius*, Münst.; *Terebratula*, very near to *T. ornithocephala*, Sow., plentiful; *Terebratula*, agreeing with *T. tetraedra*, Sow. and *T. quinquecostata*, Ziet.; and *Spirifer rostratus*, V. Buch, and *Sp. tumidus*, V. Buch, which moreover appear to pass into one another. All of these species distinctly point to the lower part of the lias.

In a grey marlstone at Tremona near Arzo occur *Terebratulæ*, of perhaps the above species; *Belemnites*, *Pecten*, *Pentacrinus*, and a small undescribed Sponge. This must, therefore, necessarily be lias.

From Monte Generoso, Brunner obtained the following lias fossils: *Terebratula ? tetraedra*, Sow., *Spirifer rostratus*, V. Buch, *Sp. tumidus*, V. Buch, and *Sp. Walcotii*, Sow. [T. R. J.]

On the Geosaurus maximus. By Th. Plieninger.

[Würtemb. Jahresb. 1849, v. 252–253, and Leonhard u. Bronn's Jahrbuch f. Mineral. 1850, p. 128.]

A block of the so-called Ulmer Portland-oolite contained a fragment of a lower jaw from near the symphysis, with seven large conical teeth. These were hollow for two-thirds of their height; open at the base; with a two-edged point; and bent inward and backward. The author had described them under the name of *Geosaurus maximus* in the Jahresb. ii. 150.

As however the teeth are evidently fixed in alveoli, this animal belongs to the Thecodont Saurians, and perhaps ought to be united to *Belodon*. [T. R. J.]

On the Archegosaurus *of the* Coal Formation. By H. v. Meyer.

[Dunker u. Meyer's Paläontograph. i. 209–215, pl. 33. fig. 13–17. Comp. Leonhard u. Bronn's Jahrbuch f. Miner. 1848, p. 468, and Jahrb. 1850, p. 104.]

The author describes a new individual of *Archegosaurus minor*, consisting of a skull and part of the neck, in H. Schnur's collection at Treves. He refers also to his discourse at the Meeting of Natural Philosophers at Aix-la-Chapelle, in 1847, where he first saw the specimen. On both occasions he has combated Goldfuss' opinion, that it was referable to a crocodile; he has moreover proved its labyrinthodontoid character, and induced Goldfuss to alter his first opinion on the subject. He proceeds to cite the notice of Goldfuss' work in the

'Jena Literatur-Zeitung,' 1848, 654; and in many respects adds much to a knowledge of the animal. He accepts Goldfuss' view that the osseous apparatus, posterior to, and in connexion with the skull, belongs to the bone of the tongue; and quotes also Goldfuss' words, that the Archegosaurus, by the presence of scales, affords a proof, that there existed, in the case of the mailed reptiles of the ancient world, representatives of a regular larval state; just as in the case of the Batrachians we have the fish-reptiles of the present day.

The *Sclerocephalus Haeuseri*, Goldfuss, lastly, appears to the author to agree in the formation of its head, even more than the Archegosaurus, with the Labyrinthodons, and must therefore also be numbered amongst the Saurians. [T. R. J.]

On the occurrence of Ozokerite *in the* Wettin Coal District. By Herr Breslau.

[Karsten's Archiv für Mineralogie, Geognosie, u. s. w., B. xxiii. H. ii. pp. 749–751*, 1850.]

The occurrence of the Ozokerite in the Wettin coal district is confined to a cleft found in the Neutzer Zuge, in the year 1848, in the farthest shaft of the Burghofer pits, at $23\frac{1}{4}$ to $24\frac{3}{4}$ fathoms, and some neighbouring clefts, in the sandstone that is situate between the shelly schist, forming the uppermost beds of the coal formation, and the limestone that overlies the uppermost coal bed. The sandstone alternates above with a clayey rock, and below with a calcareous claystone; and is characterized by its greenish-grey colour, its fine grain, its clay partings, and by its general want of mica. As an exception, that portion of it, which is otherwise altogether free of intervening laminæ, contains a trifling layer of reddish-brown clayey sandstone.

The cleft begins at $\frac{3}{8}$ of a fathom above the brownish-red sandstone layer, passes through it, and terminates at the uppermost bed of the calcareous claystone, at $1\frac{1}{2}$ fathom above the upper coal bed. Its strike is hor. 2, 2; and its dip is about 80° E.S.E.

The sides of the cleft are covered with calc-spar, which is here and there crystallized in druses, and on the sides near the middle of the cleft is generally beset with small crystals of sulphur-pyrites,—hexahedral iron-pyrites, Mohs. The remainder of the cleft is occupied with the Ozokerite.

The cleft is very unequal in size; sometimes it expands to half an inch, and is sometimes contracted to $\frac{1}{8}$ inch. This circumstance, on account of the laminated texture and symmetrical arrangement of the contents of the cleft, acts in suchwise on the variable quantity of materials present, that towards the middle of the cleft the Ozokerite is almost absent; and, whilst the mass of Ozokerite attains a thickness of $\frac{1}{4}$ inch where the cleft has its greatest width, the cleft at its narrowest portions is occupied with calc-spar only.

The small neighbouring clefts, running parallel to the chief cleft, exhibit similar contents, having a similar symmetrical arrangement

* Accompanied in the "Archiv" by an illustrative Section.

from the sides towards the middle. Calc-spar is always the most plentiful constituent, and is never absent when Ozokerite occurs.

The rocks of this district have a conformable stratification, the strike being hor. 4, 2; and the dip 12° S.S.E. Nowhere is an intrusion of the cleft visible in the schist formation, nor in the neighbouring rocks. The sandstone in its neighbourhood is either of a pale colour or bleached, and contains only sulphur-pyrites in little nodules. The red colour of the sandstone layer, noticed above as an intermediate stratum of the greenish-grey sandstone, is quite distinct from the cleft, and independent of the occurrence of the Ozokerite. The coal of the "upper bed," from the deepest part of this pit, which, with the exception of the somewhat variable uppermost bed, the so-called roof- or first-coal, is of very good quality, is nearly throughout this part of the district subject to discharges of combustible gas. We may perhaps presume that the origin of the Ozokerite is connected with this condition. The circumstance of no connexion being proved to exist between the Ozokerite gas and the coal beds in this pit, constitutes no objection to this connexion existing elsewhere.

The Ozokerite of Wettin, in its occurrence in the neighbourhood of coal beds, resembles the Ozokerite of Slanik in Moldavia, that of Gresten near Gaming in Austria, and that of Newcastle-on-Tyne. It has a yellowish-green colour, and is so soft that it may be kneaded between the fingers. [T. R. J.]

On the Crinoidea *of the* Jura Formation. By P. Merian.

[Basel. Verhandl. 1846–1848, viii. 27–29, and Leonhard u. Bronn's Jahrb. f. Mineral. 1849, p. 876.]

This notice is supplemental to a communication previously made on the subject by Desor. *Apiocrinus Meriani* [Desor], Goldfuss, pl. 55 (with the exception of fig. D, which is *A. Roissyanus*, D'Orb.), belongs to the so-called Sequanian formation,—the lowest portion of the Portland oolite, where it commences to be coralliferous, immediately above the coralline oolite. This species is often confounded with *A. rotundus*, Miller, which occurs much deeper, in the Bradford clay. The former is distinguished from the latter "by two small accessory plates between the two middle pieces of the body; further, the basal pieces form a great part of the cavity, nearly as great as that of the first middle pieces in *A. rotundus*." *Millericrinus* (*Pomatocrinus*) *Hoferi*, from the same formation, is a species with a semiglobular body, and by its uppermost column-joints is allied to *M. mespiliformis*, Schlot. sp.; it has been already figured by Hofer, Act. Helvet. iv. no. 48. pl. 8. fig. 19–21, and only lately again discovered by Koechlin. *Millericrinus polycyphus*, Agass. [Desor?], was until lately known only by its stem-joints, which occur with the heads and other parts of *M. rosaceus*, Des. [Schlot. sp.?], in the lower beds of the coralline oolite, in the *terrain à chailles*. Chr. Buckhardt has now however discovered near Fringeli, in the Canton Solothurn, the body portion of *M. polycyphus*, which turns out to be a species of *Apiocrinus*. [T. R. J.]

TRANSLATIONS AND NOTICES

OF

GEOLOGICAL MEMOIRS.

On Fossil Ants. By Prof. O. Heer.

[Mittheilungen der Naturforschenden Gesellschaft in Zurich. Heft ii. pp. 167–174, 1848.]

The Ants are amongst the most numerous of the fossil insects both at Œningen* and Radoboj, and offer many points of interest to the geologist. We especially refer to the following:—

1. Nearly all the fossil Ants are winged, and either male or female; two specimens only of the neuters have as yet occurred to me, although these latter without doubt constituted the majority in the ancient world. The reason of this is very clear. The winged Ants only could rise into the air, and so be driven into the water, where some of them would perish and be covered up in the mud.

But these fossil Ants clearly show that this covering up by the mud must have been very sudden, and much more rapid than in our existing lakes and ponds. The wings of Ants are but very feebly attached to the thorax; they remain on only until pairing takes place, and then fall off of themselves; and indeed even before this they are very easily separated. Now were the Ants to lie even a short time in the water before they were imbedded, the wings would surely fall off.

2. Among the fossil Ants many more females than males occur both at Œningen and Radoboj. I have altogether examined 279 specimens of fossil Ants, of which 208 are female, 69 male, and 2 neuter. From Œningen there are 118 females and 40 males, and from Radoboj 90 females and 29 males; there being obviously at both localities about three times more females than males.

Among existing Ants an inverse proportion obtains; for, according to the researches made by Huber, there occur on an average three times more males than females. Probably the same proportion also existed in the extinct fauna; but more females fell into the water, being feeble and unwieldy, and so perished in greater proportion than the more active and lighter males. Hence also arises the suggestion

* [See Description of the Freshwater deposits of Œningen, and Observations on their Fossil Fauna and Flora, by Sir R. I. Murchison, Trans. Geol. Soc. 2nd Ser. vol. iii. Part 2. pp. 277–290, and Quart. Journ. Geol. Soc. vol. v. pp. 233–237.—Ed.]

that the Ant-swarms did not suddenly perish from outbursts of steam or from any other such-like cause, for all the individuals of a swarm would in that case have fallen together into the water and have become fossilized. This probably was not the case, as the males have for the most part escaped. It is also rendered unlikely by the circumstance that in Œningen large groups of Ants are never found together in one stone, but generally only a single specimen, or at the most two or three. At Radoboj a greater number of individuals often lie together; but for this, as we shall see, there is another explanation.

3. At Radoboj slabs of stone often occur on which a great number of organic remains are assembled together. There are found, for example, on one stone of a few square inches, one specimen of *Formica pinguis*, three of *F. pinguicula*, one of *F. Hesione*, one of *F. Telamon*, three of *F. ophthalmica*, one of *F. oculata*, one of *F. Hecuba*, one of *F. Priamus*, one of *Bembidium*, and various fragments of plants. On another stone we find *Formica pumila*, *F. pumilio*, *F. pinguicula*, *F. obscura*, *Amphiotis bella*, *Harpalus tabidus*, a Gnat, and a *Buprestis*. We often find on the same stone leaves of trees, and still more abundantly various-sized fragments of *Cystoseirites communis*, Unger, a marine Alga, which is one of the most abundant plants at Radoboj. This clearly proves the former presence of sea-water, into which the land-animals fell; and hence we can explain why the larvæ of the *Libellulæ* are absent here, which play so important a part at Œningen. In the place of the larvæ we have at Radoboj some full-grown *Libellulæ*; these animals, therefore, were existent at both places at the same time. There was evidently at Radoboj during the tertiary epoch an arm of the sea into which a river flowed, and in which river the larvæ of the *Libellulæ* had lived, together with water-beetles, a pair of which I here found fossil; for as these insects never inhabit sea-water, but live only in fresh water, the circumstances of the case point to just such an inflowing river-stream at this place. The condition of the organic remains bears evidence to this former distribution of land and water at this place. In such an arm of the sea with a river flowing into it, the sea-plants would have been here and there drifted to shore, together with masses of land-plants and the animals that had perished in the water, where they must have lain in great confused heaps promiscuously washed up. And indeed in suchwise do we meet with them on the afore-mentioned slabs of stone, which display just such confusedly-arranged and drifted masses of plants and animals.

The organic remains do not occur under such circumstances at Œningen. It is only the larvæ of *Libellulæ* that we here sometimes meet with in great assemblages, which however are only such as those in which these animals are found living at the bottom of the existing ponds and ditches. And hence we have an additional proof that at Œningen a small quiet lake existed, the water of which was subject only to trifling motion.

4. A fourth point worthy of consideration with respect to the fossil Ants is the great abundance of the individuals. From Radoboj and

Œningen together I have examined 279 specimens, belonging to 55 species: from Œningen 158 specimens of 28 species; from Radoboj 119 specimens of 34 species.

All the existing species of Ants, as is well known, present astonishing swarms of individuals. We have in Europe only about 40 species of Ants, and yet these creatures are amongst the commonest of insects that in summer enliven hill and valley. This proportionate abundance indeed existed also in the ancient world. On account of this abundance of individuals, it is easy to collect individuals of the species that have lived at Radoboj and Œningen; and hence we may consider these 28 species from Œningen and 34 from Radoboj as tolerably well representing all the species of Ants then existing at these places; and we may be said to have before us a tolerably perfect collection, from these localities at least, of the Ants of that period. Indeed we may come to a further conclusion; the Ants have always a very wide extension, and most of the species living with us are found throughout Europe. These 55 fossil species, therefore, may generally and more or less perfectly represent the Ants of Tertiary Europe.

5. The Ants are of importance in the fifth place, in that they readily afford us the most numerous data for the comparison of the Œningen and the Radoboj faunæ. Both belong to the tertiary epoch; still it is not precisely determined whether they were quite contemporaneous or otherwise, and this question can be solved only by a strict comparison of the plants and animals of both localities. Of *Coleoptera*, Radoboj and Œningen have only one species in common (*Telephorus tertiarius*), of *Hymenoptera* also only one (*Termes pristinus*), and of *Orthoptera* none. We must remember that these forms occur at Radoboj only as a very few species, and that we are as yet acquainted with a much smaller number of insects from Radoboj than from Œningen. On the other hand both localities, as we have already seen, are very rich in Ants. Of the 34 species from Radoboj there are only seven that occur also at Œningen, being about $\frac{1}{5}$ (the proportion of *Coleoptera* being $\frac{1}{18}$, and that of *Hymenoptera* $\frac{1}{8}$). We must here also notice, that among these 34 species there are eight which, being males, can probably be placed in the other species (females), and consequently there remain only 26 species. Of the seven species that are common to the two localities, one is lost for the same reason, reducing the number to six; and thus not quite one-fourth of the whole number of the species are common to Radoboj and Œningen, which may be considered as an evidence of the contemporaneity of the two faunæ. We have to bear in mind that Radoboj lies near about 7° more easterly and 2° more southerly than Œningen, and that from this cause the existing fauna and flora of these localities differ considerably one from another, Radoboj having a more southern character; and the same is the case with regard to the fossil characters of this locality.

The family of the Ants increases at the Tropics to very numerous species, and there occur in warm countries some peculiar genera, as *Atta* and the large *Ponera*. These genera are found also at Radoboj, and indeed it is here that they appear for the first time, but they do

not occur at Œningen; and Radoboj has absolutely a greater number of species of Ants than Œningen, although Œningen is richer in other insects, and although Œningen Ants are much more frequently found in collections. The above goes to prove the more southern character of the Radoboj fauna. With this the flora also agrees; for at Radoboj three species of Palm (*Flabellaria maxima*, Unger, *Fl. Freyeri*, Unger, and *Phœnicites spectabilis*, Unger), a *Smilax*, and a *Ficus*, occur in connexion with other southern forms. The extinct fauna of Œningen is of a more southern character than what obtains at Œningen at the present time, and comes nearest to the existing fauna of the Mediterranean; but that of Radoboj is yet more southern, and indeed appears to be somewhat subtropical; but this also may be explained by the more southerly position of the district.

6. This brings us in the sixth place to a comparison of the fossil with the existing Ants; and here I will confine myself to a few important points. First of all I would observe, that the genus *Myrmica*, which plays an important part in the existing fauna, some of its species being the most abundant in the whole family, is but feebly developed in the fossil state. I have met with only 26 specimens (22 from Œningen and 4 from Radoboj) belonging to 8 species. It was therefore at that time less plentiful, particularly at Radoboj, than at present. On the other hand it occurs in two strikingly beautiful, large species, *Myrmica macrocephala* and *M. tertiaria*. The latter of these was widely spread, since it is found at Œningen, Parschlug in Steiermark, and Radoboj. The former, on the contrary, occurs only at Œningen, but there it was the more plentiful species; it appears for the most part to agree with *Myrmica barbara*, Fabr., of North Africa.

The genus *Atta*, as before remarked, occurs only at Radoboj, and is represented by three, or if we deduct a male, by two species. One of these resembles in general form and in the venation of the wings the singular *Atta cephalotes*, Auct., which is plentiful in tropical America, and there often penetrates in great swarms into the dwelling-houses, and destroys all vermin, as flies, bugs, &c. The other species may be compared with *Atta destructor*, Latr., occurring in the south of Europe, which inhabits sandy places, and constructs an entrance to its habitation in the shape of a tube or tunnel formed of sand. The whole genus, with the exception of a single species found in the south of France, is extra-European, and more particularly found in the warmer parts of America.

Of the genus *Ponera* one species (*P. contracta*, Latr.) is frequently found with us, but it is a small, insignificant species. The warmer parts of America, on the other hand, afford a number of fine, large species. Three species occur at Œningen, Radoboj, and Parschlug, which for the most part remind us of these tropical forms, and one of which appears to be closely related to *Ponera apicalis*, Latr.

By far the majority of the fossil Ants belong to the genus *Formica*. This is divisible into two groups; in the one there is but one discoid areola [Discoidal-zelle] in the venation of the wing, and in the other there are two such areolæ. They differ also in their mode of living;

the first living in small societies in dry trunks of trees, from which circumstance they may be termed Wood-Ants, whilst the others live for the most part in the earth and under stones, or construct their habitations of little fragments of plants. The former predominate in warm countries, the latter in temperate and cold climates. It is worthy of remark, that nine species of these great Wood-Ants occur at Radoboj and Œningen (the latter having eight and the former four species). One of these, *Formica lignitum*, Germar, is very similar to our *Formica herculanea*, Latr., inhabiting the trunks of the pine and fir, and probably lived in the trunks of the cypress of the ancient Œningen forests. This species is found also in the brown-coal of Bonn.

The second, *F. gravida*, corresponds to *F. æthiops*, Latr., that lives in Central Europe. And for the remaining members of this group I cannot find analogous living species.

With regard to the Ants of the second group, I will mention, that one, *F. Thetis*, is similar to *F. rufa*, which is so plentiful with us in woods, and here constructs great conical heaps of fir-leaves and fragments of wood; another, *F. ophthalmica*, corresponds to the Black Ant, *F. nigra*, which is widely spread throughout Europe.

[T. R. J.]

Pseudomorphosis of CALAMINE *and* CALC-SPAR *from the* SEVERIN MINE, *in the neighbourhood of* NIRM, *near* AIX-LA-CHAPELLE. By V. MONHEIM.

[Verhandl. d. Naturhist. Vereins der Preuss. Rheinlande, 1849, V. p. 33, and Leonhard u. Bronn's Jahrb. f. Miner. 1849, p. 862.]

IN breaking a large piece of blende there was found in the inside a druse-cavity, in which at one spot small, but very regular crystals of galena occurred, also minute crystals of iron pyrites, and many other crystals of a yellowish white colour, which were either combinations of the more obtuse calc-spar-rhombohedron with the six-sided prism, or had besides flat extremities. These crystals were situated on the blende, the iron pyrites, or the galena, and were either quite hollow, or their interior was occupied by innumerable, infinitely small, regular forms of the same substance.

Their chief constituent was, according to our analysis, carbonate of the oxide of zinc; but they contained also a large per-centage of the carbonate of the oxydule of iron, some carbonate of lime and carbonate of magnesia. Amongst these hollow crystals were situated a few, somewhat elevated, white crystals of a similar shape, which were evidently to be regarded as calc-spar. Hence we are warranted in concluding that the above-mentioned hollow crystals must be crystals of calc-spar transformed into zinc-spar (calamine), or, more correctly speaking, iron-zinc-spar. They might have been formed thus: water impregnated with carbonic acid and containing in solution carbonate of the oxide of iron, together with some carbonate of the oxydule of iron and a little carbonate of magnesia, came into contact with the calc-

spar crystals, and, taking up the much more soluble lime, allowed the less soluble carbonate of zinc to separate itself and be deposited, together with some of the other carbonated salts, in the place of the isomorphous carbonate of lime, the crystals thus formed having the appearance of large perfectly developed zinc-spar crystals; some, however, with rough surfaces, as if a mass of small zinc-spar crystals was covered with regular calc-spar crystals.

[T. R. J.]

On the Fossil Wood *collected during* Middendorf's Travels *in* Siberia. By Prof. Göppert.

[Sibirisch. Reise, I. i. 10, pl. 7–10, and Leonhard u. Bronn's Jahrb. für Mineral. u. s. w. 1850, pp. 126–128.]

From the Tundra to the river Boganida in 71° N. lat., the fossil *Pinites Middendorffanus*, Göpp. (pl. 7. figs. 1–4) *, occurs; the wood is permeated by carbonate of lime; the structure is similar to that of the existing Pines. From the banks of the river Taimyr in 74° N. lat. three species are obtained. The characters of one species (pl. 7. figs. 5–17 and pl. 8. figs. 15, 16) are rendered indistinguishable by reddish brown oxide of iron; it is very similar, both in outward appearance and in the thickness of the annual rings, to some fragments from certain deposits at Berlin and in Silesia; another, converted into shining black coal, is the *P. Baerianus*, Göpp. (pl. 8. figs. 12–15); and the third (pl. 8. figs. 17–20), silicified and having the appearance of a greyish brown hornstone, is so much weathered, that nearly all the organic tissue between the siliceous casts of the cells has disappeared; hence no specific determination can be arrived at.

On the banks of the river Taimyr, in 75° N. lat., two fragments of wood were found in the immediate neighbourhood of a skeleton of a mammoth, and apparently under similar geological conditions. These were but slightly changed; they had the appearance of having been for a long time in the water, and their specific gravity was lessened. One of the specimens is identical with larch-wood (*Larix Europæa, L. Sibirica, L. pendula, L. microcarpa*, and the fossil *Pinites protolarix*, Göpp.), and cannot be specifically distinguished; whilst the other is identical with fir-wood (*Pinus abies* or *picea, Abies Sibirica, Pinus picta*, and others).

None of the above fossil woods are apparently older than the tertiary formation; and the last two (subfossil) species, found near the mammoth, are indistinguishable from the existing larch and fir species of Siberia. The place where they were found, however, is far to the north of the districts occupied by the existing species; they must therefore have been carried by river floods, probably in company with the mammoth, from more southerly districts to the spot where they were found.

* The plates do not accompany this translation.

Middendorf adds, that Göppert, in examining this fossil wood, has arrived at the following conclusions, which coincide with the views that he himself was led to take by observations made on the spot: namely, that all the fossil wood and coal as yet found in the Taimyr country dates from a very recent epoch of the earth's history. That the fossil wood of Northern Siberia belongs to the existing flora, and resembles the drift-wood that is at the present day washed up by the waves on the northern coast. That this fossil wood, both on the lower part of the river Taimyr, as also in the districts near its source, occurs far beyond the northern limit of the growth of trees, especially of fir forests. That in its organization and state of preservation it quite agrees with the drift-wood still washed up by the sea. That well-preserved and unworn marine shells, of species still existing in the Arctic sea, occur in the same beds with the fossil wood. And that, therefore, the fossil wood probably found its way to the Arctic sea by the same course as that traversed by the drift-wood of the present day, which is brought down to the sea from central and southern Siberia by the large rivers, particularly the Jenisei and the Lena, and after drifting about for some time, is stranded on the coast. That the Tundra was at that time the bed of the sea is proved by the imbedded shells, the shingle, and the erratic blocks. That the Arctic sea as well as Southern Siberia already possessed at that time a climate like the present, is proved, on the one hand, by the marine shells of recent species, and on the other by the species of the fossil wood. That, lastly, the Mammoth found at the Taimyr participated with the fossil wood in the circumstances of its fossilization; and that, together with the wood, it was brought down to the sea from its native locality near the upper (southern) parts of the Siberian rivers; that the low temperature of the rapid rivers and a covering of ice for a time favoured its preservation, until it was silted up on the sea-coast, where ultimately its decomposition formed the layer of mould, evidently of animal origin, that was found to envelope the skeleton *.

Middendorf observes that this animal, possibly, like the elk of the present day, was enabled by the peculiar structure of its teeth to feed on the twigs of the fir; in which case it did not suffer want of food.

Middendorf had frequent occasion to wonder at the astonishingly long period during which the carcases of animals washed up on the shore of the Arctic sea are preserved. Even a stranded whale, thrown up on a sandy shore by strong breakers during an ebb tide, becomes quickly imbedded; its blubber, however, remaining fresh and well-preserved for a considerable time afterwards; whilst a carcase thrown up high on shore by a flood-tide is left exposed on the surface, and is quickly consumed even to the strongest bones by beasts of prey.

With regard to the mineralized and carbonized woods of the first-mentioned locality, Middendorf gives up his opinion of their being of the same species as the subfossil woods subsequently described;

* [Compare the chapter on the Mammoth Period, Murchison's Russia and the Ural, pp. 492–506.—Ed.]

but apparently insists that the former also were deposited as drift-wood in the locality where they are found, and became mineralized subsequently.

[T. R. J.]

On the History *of* Insects. By Prof. O. Heer.

[Leonhard und Bronn's Jahrb. f. Miner. u. s. w. 1850, pp. 17–33.]

The great Class of Insects, which furnishes four-fifths of the existing species of the animal kingdom, has two chief divisions. In the one (the Ametabola) we have an imperfect, in the other (the Metabola) a perfect metamorphosis; that is, in the former there is no quiescent pupa-state, and the metamorphosis is accompanied by no striking change of form; in the latter there is an inactive pupa, that takes no nourishment, and so great a change of form that only by watching the progress of the metamorphosis can we recognise the pupa and the imago as being the same animal. The Metabola correspond, as it were, to the flowering plants; the Ametabola to the Cryptogamia. It is well worthy of remark, that among Plants the Cryptogamic, and among Insects the Ametabolous, first appeared upon our earth. The most ancient forests, composed of tree-ferns, club-mosses, and equiseta, were inhabited by *Locustæ* and *Blattæ*, the first of insects. There have not as yet been found in the carboniferous and triassic rocks any traces of insects that can be with certainty referred to any of the other Insect-orders. And of these Orthoptera at present we know of only six species belonging to these most ancient times, in which indeed insects appear to have been extremely scarce. Nor need we wonder, if we consider that at present also our Lycopodia and Equiseta harbour no insects, and the Filices very few. The hosts of insects, therefore, that live on the flowers and their honey, on the fruits and seeds, could not at that time have been in existence, the vegetable world being then destitute of flowers and fruits.

The ametabolous insects also play the chief part in the jurassic period. Here they appear as very large Locusts and Dragon-flies, the latter belonging to the *Æschnidæ* * (including the *Gomphi*) and the *Agrionidæ*, as a few Termites and a long series of beaked insects.

Near these, however, in the jurassic rocks occur also some insects of the second division; namely, a few Flies, an Ant †, and a number of Beetles. The flower-insects, on the other hand (as Bees and Butterflies) ‡, appear to have been wanting at this period.

This is also the case in the succeeding period, that of the Chalk,

* The *Libellula Brodiei*, Buckman, in Brodie's 'History of the Fossil Insects in the Secondary Rocks of England,' is clearly an *Æschna*.

† I look upon the *Apiaria lapidea*, Germar, to be an Ant, on account of the peduncled hind-body. In its bearing also it much more resembles an Ant than a Bee.

‡ The *Tineites lithophilus*, Germar (Munster, v. 88), is according to my view a Termite. Not only on account of its size can it not be a Moth, but still more on

in which neither Butterflies, nor Bees, nor Hymenoptera generally have been found. The Beetles, on the other hand, occur in somewhat larger proportion.

In this cretaceous period there existed islands rising from the sea and chiefly wooded with fir-trees; bearing also Palms, Dragon-trees, and tree-like Lilies, together with which the first dicotyledonous trees occur. These, however, appear to have been as yet very few in number, it being only in the following period, the tertiary, that they became plentiful, forming from this time an essential proportion of the vegetable kingdom. In company with the creation of dicotyledonous trees and phanerogamic herbs, the Insect-world appears to have been first developed at this period in all its orders and in more manifold forms. Whilst at present we are acquainted with only 126 species of insects altogether from the earlier geological periods; from the two tertiary localities Œningen and Radoboj I know of about 443 species. Amongst these are present all of the seven Orders of recent Insects; but, nevertheless, in different numerical proportions to those of the existing faunæ. In these the Ametabola form about 0·10, the Metabola 0·90. Of the Œningen and Radoboj species, 124 belong to the Metabola and 319 to the Ametabola; the former making more than a third. We see therefore that at this period the Ametabola were much more numerous in proportion than the Metabola, although not more in the mass, as in former geological periods. The Bees and Butterflies appear as new chief types, presenting however only very few forms. In the existing creation only have these Insect-types been developed in their full richness of form and splendour of colour; and this may be the better understood inasmuch as in the tertiary period the land was almost entirely occupied with woody plants and forests, and offered but few herbaceous flowering plants from which the Butterflies and Bees could derive their nourishment.

With regard to each of the Orders of Insects, the material we have at present is much too limited to enable us to give a perfect history of this great Class; nevertheless we are enabled to offer a few hints on this hitherto little-known subject.

I. Among the Ametabola we meet with the beaked Insects in numerous families. In the jurassic period appear some large water-bugs [*Nepidæ*, &c.], some land-bugs [*Cimicidæ*], and *Cicadæ*. In the cretaceous period appear *Aphides*, and in the tertiary period there are very beautiful *Cicadæ* and large species of *Cercopis*, which are characteristic of this *Rhynchota*-fauna [*Hemiptera*]; there are present

account of the short thorax, and legs destitute of spines, in which respects it agrees with the Termites, as well as in the long, narrow, fork-veined wings, folded over the body. I also regard as a Termite the *Apiaria antiqua*, Germar (Nov. Act. xxii. 2). The venation of the wings at once shows that this animal cannot possibly belong to the Bees; on the contrary, most probably it is referable to the Termites. The wings are not well-preserved in their whole length, hence their apparent shortness. The fossil from Solenhofen, figured as *Sphinx Schræteri* (Schröder, Neue Literat. I. Taf. iii. 16), is so badly drawn that nothing can be done with it.

also numerous species of Bugs, which are very similar to existing species.

Of the second great order of ametabolous Insects, the *Gymnognatha* [*Neuroptera*, &c.], I have particularly to notice the *Libellulæ* and the *Termites*, both which families have a high geological importance. They commence early in the jurassic period, and have continued throughout the cretaceous and tertiary periods down to the present, although now they no longer play the part they formerly did. The jurassic *Libellulidæ* are all large, beautiful animals, and are all *Æschnidæ* or *Agrionidæ*; true *Libellulæ* occur for the first time in the chalk. Near to the genus *Æschna* come *Gomphus* and a peculiar genus *Heterophlebia*, observed as yet in the jurassic rocks only. The *Agrionidæ*, which are much scarcer than the *Æschnidæ*, belong for the most part to the group *Lestes*, characterized by many fine areolæ in the reticulations of the wings. A peculiar group, *Sterope*, also occurs in the lias and is again found at Œningen, but has since become extinct. In the tertiary period there existed, besides the genus *Sterope*, other members of the *Agrionidæ*, particularly species of *Lestes*; and species of *Æschna* very similar to existing forms were present, and *Libellulæ* proper. These were so plentiful at Œningen, that their larvæ were amongst the most common animals there. It appears therefore that in this family the *Æschnidæ* and *Agrionidæ* first occurred; and of the latter the many-celled-winged [vielzelligen] before the rest. Further, the genus *Libellula*, at present so rich in species, first appeared in the Chalk period, and was developed in numerous species in the succeeding tertiary epoch. Still more remarkable, however, than the *Libellulæ* are the fossil *Termites*, those singular animals that are at present so abundant in the Tropics, constituting one of the greatest land-plagues of hot countries. Like the Ants they live in large communities, building themselves curious habitations, and feeding on vegetable matter. The *Termites* (two species) appear first in the jurassic, and subsequently in the cretaceous and tertiary beds. I am acquainted already with nine species, the majority of which are remarkable for their size; one species is larger than any one of the existing species. The *Termites* are most numerously found at Radoboj; and I know of two species from Œningen and three from amber. Some of these tertiary *Termites* resemble Brazilian species, but the majority exhibit peculiar, extinct forms. Their size and their great abundance allow us to infer the existence of a rich vegetation in the demolition of which they were necessarily occupied.

That the *Orthoptera* comprise the oldest known insects has been already mentioned. It is important to observe that the *Blattidæ* first appeared in the carboniferous epoch, and have continued through all subsequent periods down to our own time, and indeed in very similar forms. The same may be said also of the *Acridii* and the *Locustæ*, with which the Locust-type commences, continuing down to the present. Most of the tertiary Locusts belong to the *Œdipoda*, but there also occurs the genus *Gryllacris*, still living in India.

II. Of the Metabola we first meet with the Flies. At present these

occur in nearly the same numerical proportion as the *Hymenoptera*; the latter, however, are somewhat richer in species. The Flies had the same proportion in the tertiary period also. I am acquainted with 80 species of *Diptera* and 87 of *Hymenoptera* from Radoboj and Œningen*. The order of *Diptera* comprises two great natural divisions—the *Nemocera* [langhörnigen] or gnat-like Flies and the *Brachocera*. At present the first form about $\frac{1}{7}$ and the latter $\frac{6}{7}$ of the species; there are known 1161 of the *Nemocera* and 7100 of the *Brachocera*. The *Nemocera* were the first to appear, and were followed a little later by the *Brachocera*, which at Œningen form only $\frac{1}{3}$, at Radoboj about $\frac{1}{4}$, at Aix also about $\frac{1}{4}$, in the amber about $\frac{1}{5}$, whilst at present, as above remarked, they constitute $\frac{6}{7}$ of the *Diptera*. The fact that, in all localities from which we have as yet obtained fossil Flies, the *Nemocera* so decidedly predominate, clearly proves that this proportion was not dependent on local causes, but that the *Nemocera* were indeed the oldest amongst the *Diptera*. With this also corresponds the fact that all the known Flies of the cretaceous age (15 species) belong to the *Nemocera*, not any to the *Brachocera*. The few specimens of Flies from the jurassic rocks with which we are acquainted are unfortunately so badly preserved that no correct determination of their characters can be arrived at.

Nor is it very difficult to suggest a reason why the gnat-like Flies [*Nemocera*] were the first to appear, and have down to the present time formed the majority of the Fly species. The *Brachocera* live chiefly on flowering and herbaceous plants; we see them in crowds basking on the flowers of the umbelliferous and syngenesious plants; on the contrary, the *Nemocera* fly about in woods and thickets, and particularly affect damp, watery places. Their larvæ live partly in water, partly in damp woody bottoms, in rotten wood, and in great numbers in fleshy fungi; whilst the larvæ of the majority of the *Brachocera* inhabit different flowers, fruits, seeds, and roots, especially of herbaceous plants. Everything, however, points to the fact that in the tertiary period the land was occupied chiefly by tree-like plants; and further, the many species of willow and poplar, as also the swamp cypress (*Taxodium*), point to extensive swamps and morasses. If we imagine a widely-extended dark damp wood, traversed by small streams and interrupted by morasses, we have altogether the conditions requisite for the gnat-like flies. Of the fossil *Nemocera* discovered at Œningen and Radoboj, three have lived as larvæ in the water, and ten in fleshy fungi; we may therefore feel assured of the occurrence of such fungi in these ancient woods, although as yet no fossil remains of them are known. There were 47 species also of Flies, and that too the majority, living without doubt in damp woody grounds and rotten wood. Such damp woodlands were very probably also the favourite resorts of the numerous *Pachydermata* of

* I would remark, for those who possess my work on the Insect-Fauna of the Tertiary Formation of Radoboj and Œningen, that since its publication I have met with a considerable number of new species, which will be described in a supplement. The numbers given in the present memoir refer to species known to me down to August 1849.

that age. The Tapirs and wild swine are still met with in such localities; and these, as also the Elephants, Mastodons, Rhinoceroses, and some subordinate similar species, belong to the most plentiful and most widely-spread of the higher animals that during the tertiary time inhabited the dark forests of our countries.

Of the *Diptera*, the larvæ of which lived in the earth, there are the *Bibiones*, which occur in an astonishing abundance. I am acquainted already with 34 species of such *Bibionidæ*, whilst at present, from the whole of Central Europe, only 44 species are known. It is here worth noticing, that of those 34 species, 22 only are included in the genus *Bibio* (of which there are as yet known only 18 European and 11 American species); 2 species belong to the Brazilian genus *Pleceia*, and 11 species to two newly instituted, peculiar, extinct genera. I was surprised also to find amongst the Aix-la-Chapelle fossils one of these new genera, that occurs also at Radoboj, at Œningen, and in the brown coal of Orsberg, the genus *Bibio* being there well-represented. We see, therefore, that the *Diptera* of the tertiary epoch culminate in the group of *Bibionidæ*. I have not found in a fossil state any Thorn-gnats [*Clitellariæ*?], Gad-flies [*Tabanidæ*], or flies parasitic on warm-blooded animals, and these probably belong only to the existing fauna. On the contrary, *Asilidæ* occurred, which chase other flies and suck their blood; and this mode of life, without doubt, obtained at that time.

It has been already mentioned that the Butterflies occurred at a later period only, and were but few in number even in the tertiary period. On the whole I am acquainted with only 7 species from Radoboj and 2 from Œningen; and there are only a few species known from Aix-la-Chapelle, and a few from amber. It is remarkable, that of these *Lepidoptera*, two species have great similarity with East Indian species, whilst one is comparable with our Thistle-butterfly and one with our [Gras-Sackträger].

If we glance at the *Hymenoptera* of the ancient world, we shall be struck with the astonishing abundance of Ants in the tertiary epoch. I am acquainted with 66 species from Œningen and Radoboj; there are many also at Aix-la-Chapelle and in amber; the number of the tertiary species of Ants thus amounting to almost a hundred. If we consider that at present we are acquainted with only 40 European species of Ants, this fact of the richness of the species will be very surprising. And the more remarkable it is, since nearly all the existing genera are found amongst the tertiary Ants; and there occurs moreover a peculiar extinct genus (*Imhoffia*, Heer); thus the Ant-type in the ancient world appears to have been developed in much richer forms than at present. The Ants were particularly abundant at Radoboj, where they compose the majority of the fossil animals. That locality affords stones that are quite covered with Ants; and indeed often as many as six different species are found lying confusedly together on the same slab. What a richly luxuriant vegetation must have here existed to have supplied nourishment for such hosts of Ants, so many Termites, and Locusts; and what living multitudes must these ancient countries have produced! Whilst the ter-

tiary forests, locally at least, must have swarmed with Ants, the other families of the *Hymenoptera*, on the contrary, very sparingly occurred. Of the fossorial Wasps I have as yet met with two species only, and of these one exhibits a remarkably gigantic form. Of the *Ichneumonidæ*, which at present form the majority of the *Hymenoptera*, I am acquainted with only nine species. This is analogous to the scanty development of the *Lepidoptera*. Very many Ichneumon-flies are connected with this order of insects, since in their young state they inhabit the body of the caterpillar in which they have been deposited. At this period there existed very few Butterflies, there could, therefore, be only few Ichneumon-flies; hence we may obtain a confirmation of our former supposition, that the Butterflies belong to a later period of creation. It is also worthy of remark, that besides the Ichneumon-flies proper, there occur also in the fossil state some species that have lived in the interior of the larvæ of the same. Thus, the species of the genus *Hemiteles* pierce, and lay their eggs in, the larvæ of the Ichneumon-flies, which inhabit the bodies of caterpillars. This genus *Hemiteles* is represented at Radoboj by one species; this remarkable and complicated relation therefore existed already in the tertiary period. The Bees, the Leaf-wasps [*Cynipidæ*], and Wasps proper, like the Ichneumon-flies, are not numerous; and in comparison with the Ants, are quite in the background. Of the Wasps proper I know of only one wing from Parschlug in Steiermark; of Bees, one Humble-bee species, some Flower-bees, and one very fine Wood-bee.

Of the great Coleopterous order of Insects the vegetable-feeders first appeared. The Weevils [*Curculionidæ*], Goat-chafers [*Cerambycidæ*], and the *Sternoxi* [*Buprestidæ* and *Elateridæ*] predominated in the jurassic period. In the cretaceous period the *Curculionidæ*, *Sternoxi*, and *Palpicornes* are the most numerous. In the tertiary period the *Sternoxi* hold the first rank, then come the Weevils, the *Lamellicornes*, the Leaf-chafers [*Melalonthidæ*], the *Clavicornes*, the *Palpicornes*, and Ground-beetles [*Carabidæ*]. We must notice that of the *Sternoxi* there are in particular the *Buprestes* [Pracht-käfer], the most important member of this group throughout the former geological periods of the earth. These *Buprestidæ* we find first in the jurassic rocks, then in the chalk, and as a multitude of fine large species in the tertiary strata. How differently conditioned is our fauna in this respect! We have some few small and insignificant species, whilst the tropics harbour a multitude of species remarkable for size and beauty of colour. The fossil *Buprestes* without doubt inhabited the woods, just as the existing species, and their larvæ lived in the interior of trees. The Goat-chafer [*Cerambyx*] appears to have been the most abundant throughout the whole of the tertiary times, whilst with us at present the *Bostrichidæ* furnish the majority of the wood-destroying Chafers. In the tropics, however, the *Cerambyces* occur still more numerously in the forests than the *Buprestes*. The *Cerambyces*, which, like the *Buprestes*, are wood-eaters, were very rare in the tertiary period, as well as the *Bostrichidæ*; we cannot, therefore, attribute the great abundance of the *Buprestes* to the

luxuriance of the forest vegetation ; but other important circumstances must have co-operated in the development of the fauna and flora generally, and especially in that of the *Coleoptera*. The *Buprestes*, therefore, are interesting in a geological point of view, entering into creation at an early period, predominating amongst the Wood-chafers in the tertiary period, and occupying an important place in the history of the development of the Beetle-tribes.

What the *Buprestidæ* are amongst the land-beetles, the *Hydrophilidæ* are amongst the water-beetles. Our waters are inhabited by two chief Beetle-families, the *Hydrocantharides* and the *Palpicornes*. At present the former predominate, and indeed not only with us, but also in the hotter countries. In the tertiary period, on the other hand, the *Palpicornes* decidedly predominated, and that especially through the *Hydrophili*. Not only do they occur in a long series of species, but also in gigantic and remarkable forms, unmatched by any living species ; indeed one very peculiar genus (*Escheria*) is become altogether extinct. That this predominance of the *Palpicornes* was not dependent on local causes, will be shown by the fact, that as yet there are known four species of *Palpicornes* and only one *Hydrocantharis* from the chalk, three species of *Palpicornes* with one *Hydrocantharis* from the jurassic beds, and that at Œningen and Radoboj together about twice more of the former than the latter occur ; whilst, on the contrary, in the present world, were we to compare the relative proportion, either generally or in the Swiss fauna, there are known about twice more *Hydrocantharides* than *Palpicornes* inhabiting the waters. In fine, the water-beetles, as also the land-beetles, have commenced with the more incomplete forms—the vegetable-feeders, and only at a later period were the more highly organized carnivorous water-beetles brought into existence.

From this examination of the history of insects arises the question *, Is there naturally a development of the perfect from the imperfect, or is the introduction of different plants and animals entirely influenced and guided by external circumstances, by climate, and by local conditions ? These latter circumstances are doubtlessly of the highest importance. But we also see that similar climates produce altogether different forms, as a comparison of the natural history of North America and of Europe, or of districts even lying nearer together, will show us. Hence we see that climate is not the only determinating condition, and that typical differences exist under similar climates ; a harmony, at the same time, existing between the plant- and animal-types and the climate in which they live. Taking into consideration the influence of external circumstances, we are prepared to expect that aquatic animals and plants must necessarily have been the earliest organisms,

* With great pleasure I find the author, altogether independently and of his own accord, by the examination of fossil insects, arrive at similar conclusions with regard to the laws of the development of organic nature, to such as, from the study of fossil remains, I have given in the 'Geschichte der Natur, Abtheil. Enumerator Palæontologicus ;' viz. (1.) the law of gradual perfection in its peculiar modification, governing through (2.) the law of progressive relation of organization to external conditions ; thence (3.) the law of increasing diversity.—Bronn.

in consequence of the predominance of the primæval ocean; and we find also, that these inhabitants of the water in general have a lower grade of organization than the land plants and animals. Thus it is evident that both of the great organic kingdoms of nature have produced their lowest, and at the same time their earliest, forms in the water. As dry land arose, so also must have arisen new conditions favourable for the existence of a multitude of new plants and animals; and that so much the more, the more the firm land increased in extent and in heterogeneousness of composition. And, in accordance with the conformity existing between the extent of the inorganic and the organic relations of the earth, the evolution of the more and more varied conditions of climate, soil, &c. would be steadily accompanied by more and more manifold forms of animal and vegetable life. Evidence of this progressive change is to be seen in the case of Insects; and is especially shown by the above-mentioned relative proportions existing between the *Metabola* and the *Ametabola*; the latter, of inferior organization and with imperfect changes, appearing first on the stage, and, in the early periods of the earth, predominating over the former. There being no marine insects, this animal type could first come only with the formation of dry land. Of the *Articulata*, to which class of animals the *Insecta* belong, the subordinate *Crustacea* first appeared, predominating, through the *Trilobites*, in the earliest geological periods *.

There are also some striking examples, previously given, in the individual orders of Insects, of the appearance of the more imperfect forms before those of higher organization. The *Hymenoptera* and the *Diptera*, however, appear to form an exception. If in the *Diptera* we begin with the *Brachocera* as the more imperfect, and ascend from them to the *Nemocera*, we ought in the *Hymenoptera* to place the Bees lower than the Ants and the Ichneumon-flies. This arrangement certainly does not seem natural. The Bees appear to me to belong to the head of the *Hymenoptera*, and the *Ichneumonidæ* to occupy a subordinate rank. The *Muscidæ*, among the *Diptera*, are analogous to the Bees, but the *Ichneumonidæ* have as their analogue the *Nemocera*, so that the latter appear to stand lower than the former, and this is supported by their more imperfect wing-structure. Under these considerations, the *Hymenoptera* and the *Diptera* would not altogether contradict the general rule, that the earth, both in the formation of its surface and in all its habitants throughout the course of time, had received continual improvements. . . . . .

A second important conclusion that I believe may be drawn from the above inquiry into the history of the Insects is, that the older an animal type is, so much the more are the tertiary related to the existing forms of that type†. Each type also commences with peculiar forms, and then gradually approaches to those of the present time. The *Vertebrata* clearly show this; of these, the fish first appear

* [Compare Prof. Agassiz's "Geographical Distribution of Animals," Christian Examiner, 1850, p. 195.—Ed.]

† This is authenticated, both generally, and among Mammalia in particular, in the 'Geschichte der Natur, Enumerator.' S. 739 ff., 909 ff., 936 ff.—Bronn.

with forms most foreign to those now existing, whilst the tertiary fish are very similar to recent forms. The *Mammalia* occur first in the tertiary period, in any force at least, and commence as new classes of animals with very bizarre forms. Thus, the mammals of comparatively late introduction are so very different from existing forms, whilst the contemporary fish, representatives of a far more ancient type, are with difficulty discriminated from their recent allies. This also holds good with Insects. The tertiary *Libellulidæ, Locustidæ, Blattidæ, Mycetophilæ, Tipulæ, Limnobiæ,* &c. are very similar to existing species, and at the same time belong to types that occurred at an early period, and have passed down through many subsequent epochs. The *Protactidæ* and the Bees, on the other hand, appearing in the tertiary age, exhibit very singular forms.

Thirdly, the oldest animal types of the present world appear also to have the widest extension on the earth*. The limit, therefore, of the dispersion of existing beings may afford at least some geological hints. As examples, I will mention that the Fungus-flies appear early in the jurassic rocks, and that of these, one species (*Mycetophila pulchella*) occurred in the tertiary age, to which one species found throughout Europe (*M. 4-notata*), and another found in North America (*M. cinctipes*), have great resemblance; also, that of the genus *Syrphus*, a tertiary species is very similar to *S. scalaris*, which is spread throughout Europe, a part of America, and Asia; and that tertiary species of *Limnobia* occur which stand extremely near the widely spread existing species; &c. But however similar the fossil species appear to be to the recent, they are, without exception, quite distinct; and the whole insect-fauna of the tertiary epoch is extinct; its fragments only, preserved to us by the rocks, give us a knowledge of the peculiar life of the ancient world.

[T. R. J.]

On the Coal-formation *near* Meisdorf *in the* Selke Valley. By Herr Giebel.

[Sitzungs-Protok. des naturwiss. Vereins in Halle, i. 1848–9, p. 29, and Leonhard u. Bronn's Jahrb. f. Min. 1850, p. 91.]

This formation, like those of Wettim and Löbejun, had been hitherto referred to the New Red Sandstone. The trial-shafts, however, in the Selke Valley have furnished the following characteristic plants, that remove all doubt of these beds belonging to the true coal-formation; viz. *Pecopteris arborescens, P. abbreviata, P. Oreopterides, P. polymorpha, Sphenopteris artemisiæfolia, Neuropteris heterophylla, N. auriculata, Annularia longifolia, Lycopodites Bronni,* &c.

[T. R. J.]

* [Count D'Archiac, M. De Verneuil, and Prof. E. Forbes have also enunciated the fact, that the fossils common to the most distant localities are such as have the greatest vertical range. Edinb. New Philos. Journ. vol. xxxvi. p. 325.—Ed.]

ALPHABETICAL INDEX

TO THE

PROCEEDINGS OF THE GEOLOGICAL SOCIETY.

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